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THE CADASTRAL SURVEY OF EGYPT

1892-1907.

BY

CAPTAIN H. G. LYONS, F.R.S.,
Hon. D.Sc. (Oxon.), Hon. Sc.D. (Dubl.),
DIRECTOR-GENERAL.

Price: 400 milliemes.

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THE CADASTRAL SURVEY OF EGYPT.

CHAPTER I.

Introduction.

In June, 1907, the maps and land-registers of the last villages of the province of Beni Suef were forwarded to the Ministry of Finance, thus completing the Cadastral Survey of Egypt, which had commenced in 1892 as a survey of State lands and developed into a revenue survey in 1896, becoming very shortly afterwards, to all intents and purposes, a cadastral survey carried out with a technical accuracy comparable to that of similar surveys in Europe. The whole of the cultivable lands of Egypt (except the distant Oases) had been surveyed and land-registers recording the area and ownership of each property had been prepared; the maps were at first drawn on the scale of 1 : 4,000, but after about one-third of the area had been finished, the extreme subdivision of the holdings in the more fertile districts necessitated the adoption of a larger scale and the remainder of the country has been surveyed on the scale of 1 : 2,500. All these maps have been printed by lithography and published, except those of the provinces of Sharqia and Beheira, which were surveyed before the present methods were fully developed, and which are since being revized and published on the scale of 1 : 2,500, Sharqia province being just completed.

Surveying has been carried on in Egypt to a considerable extent during the last ninety years, and the work of Muallim Ghali and M. Masi, 1813–1822, of Mahmud Pasha el Falaki, 1861–1874, of the Cadastre of 1878–1888, of the Hydrographical Survey of 1889–1898, amount to a total of some forty years' work on the geographical measurement of the country before the Cadastral Survey, which has just been completed, commenced. That more permanent results were not obtained from them is mainly due to a want of scientifically organized control and supervision, so that inferior work was not

detected, and the standard of accuracy was allowed to fall below that which was necessary in so densely populated a country. The circumstances of the time have usually been responsible for this, and want of funds, urgent demands for maps to be prepared within a minimum length of time and other similar causes led to much repetition of work, without producing reliable maps of the country.

During the time that the present Survey Department has been engaged in measuring the cultivable lands of Egypt, much inconvenience has been experienced from the want of any complete account of these earlier surveys. It would have been of incalculable benefit if we had known what our predecessors had done, the methods they employed, the difficulties they encountered, and the expedients they adopted; but none of these nor even the cost of their work were ascertainable. There is always much to be learned from studying the past stages in the development of any science, for as we trace the causes which have operated on its gradual growth we learn how and in which direction future progress may best be made. The more complete our knowledge is of the work which has been done in the past, the easier will it be to avoid the repetition of any mistakes which our predecessors may have made, and to introduce improvements in future work. The physical character of a country changes but slowly, and, therefore, the problems to be solved by the surveyor long remain essentially the same, so that there is more than an academic interest in collecting and discussing the methods employed in former times, however superior the present system may seem to be. When the formation of the Survey Department was undertaken in 1898, no complete account existed of the work of this kind which had been previously undertaken. References to it existed in various reports, but the detailed information concerning the methods employed, their cost, the recruiting and training of staff, and relative value of different ways of executing the work, was not available. There was no time then to undertake its compilation, but had such a work existed, subsequent work would have been greatly expedited and facilitated, and a considerable economy would have resulted. Even the maps which had been made only existed in a few cases, so that all had to be recommenced and experience alone could show gradually which of the methods employed in other countries could be most suitably adapted to the local conditions of Egypt.

Surveying is too often considered to consist of a set of rules which, if carefully followed, will produce a map of the necessary accuracy. A code of regulations, a selected text-book, a staff of surveyors trained to execute certain work in a certain way—these are frequently believed to be all that is necessary to produce a satisfactory survey. But surveying is a science, and, like other sciences, its students must not only be acquainted with the methods which have been found useful, but must thoroughly understand the principles on which the methods are based, and modify them to suit any special conditions which may occur. The surveyor must have a thorough knowledge of the science of geography if he is to produce the best results, and the geographer who does not understand the principles of surveying will make but an imperfect use of his maps.

The present report aims at recording in considerable detail the progress of the work, with such statistical information as may be instructive to surveyors both in Egypt and elsewhere. At the same time I have not limited myself to a bare technical account of these fifteen years' work, because the circumstances under which it has been done are to some extent peculiar, and are so far removed from the usual European practice that a full discussion of them may be of use to a wider circle than workers in Egypt alone. The geographical conditions are peculiar, and as these were necessarily the dominant factor in determining the detailed methods which were adopted, they are described fully. Land measurement of some accuracy has existed in Egypt for 5,000 years and more, so that the customs of to-day are the descendants of a long line of predecessors, and, it may be added, they show remarkably few signs of modification.

Leaving the geographical factors, we come to the political ones, which, unfortunately for the surveyor, have often the greater weight in deciding the way in which a survey has to be carried out; and in the present case they were no more conducive to the most favourable technical conditions of work than is usually the case.

The re-assessment of the land-tax was of primary importance, since as a result of the local administrations having been practically uncontrolled for many years, the rates of tax imposed did not in many cases correspond with the fertility of the land, and when the Commissioners of the Public Debt granted a sum of L.E. 216,000 annually for ten years from 1898 to compensate the Government for reducing the

land-tax by this amount on land where the rates were excessive, it became possible to readjust the rate of tax so as to remove the existing inequalities. The Commissioners who investigated the financial condition of the country in 1878-1879 had laid great stress on the necessity for this, and an attempt was made to deal with the matter by instituting the Cadastre of 1878-1888, but its work did not get as far as a re-assessment of the land-tax.* In 1895, however, Commissions were appointed to assess the rental value of all lands on which fixed rates of tax were being paid, but the re-assessment of the tax to be paid by each landowner could not be taken up until the limits of the village lands and their subdivisions—" hods "—had been mapped as well as the properties belonging to each individual. Some seven million feddans of agricultural lands had, therefore, to be measured, each holding had to be located, its area determined and the owner recorded, in a country where land was highly subdivided—for the average size of half the holdings was but half a feddan—and in which the boundaries between properties were seldom indicated by any visible marks. By 1897 about one-third of the country had been measured, so that nearly five million feddans had to be completely mapped and recorded within a period which had been arbitrarily fixed at ten years, since the information then available did not admit of a reliable estimate being made. The demands made upon the Survey were not only that work should be pushed on at as high a rate as possible, but that two provinces should be finished and ready for the re-assessment of their land-tax annually. To complete this task when the provinces varied greatly in area, when local authorities might or might not assist cordially, when the inhabitants of a province might be disinclined to facilitate the work, when the removal of survey-marks might retard the survey of a village for weeks, meant the introduction of a number of unknown factors into a problem already sufficiently complicated ; at the same time the work was being improved in technical accuracy and modifications were being introduced to guard against errors as far as possible. Since time was, under these conditions, the factor of most importance, everything had to be arranged so as to ensure as large an out-turn as possible in the twelve months and to make allowance for any unforeseen delays while still completing the two provinces required within the allotted time.

* See Chapter VII.

The annual grant was increased to admit of additional staff being employed, as the work was greatly hindered in Upper Egypt, where the land lay under the waters of the inundation for nearly three months, and where measurements in the field were consequently impracticable from the middle of August to the middle of November. Only by working at high pressure and by adopting every device which might save time was the work completed within the term specified.

This period corresponded, too, with one of rapid expansion in many Government departments, so that no little difficulty was experienced in obtaining employees who possessed any but the most elementary education; in fact, ability to read and write Arabic and to do simple arithmetic were the only qualifications demanded of those who were recruited for training as land-measurers. All these were Egyptians, and several English inspectors to direct and supervise were the only Europeans employed in the work of the chain survey. A few Europeans were employed in the Central Computation Office, and others in the Drawing Office, where the preparation of topographical maps on scales of 1 : 10,000 and 1 : 50,000 was carried on, but the whole of the cadastral field work, the minor triangulation, the autographic reproduction of the cadastral maps, and most of the computation was carried out by Egyptian employees under the English inspectors.

These special conditions, though greatly increasing the difficulties of carrying out a satisfactory survey, certainly make the problem more interesting for the professional surveyor as introducing factors which are likely to be often met with in new areas where lands are developing in quality or agriculture is advancing rapidly. In the present case there was the further complication of a dense population and highly subdivided land.

The problem may be stated as follows:—To carry out a cadastral survey of about seven million feddans (about 2,900,000 hectares) of land which was so subdivided that more than 40 per cent. of the holdings were under half a feddan (2,100 square metres) and to prepare the land-registers; to do this at the rate which varied from 500,000 to 800,000 feddans annually according as larger or smaller provinces were being surveyed; to keep errors both of measurement and registration as low as possible, although no legal powers existed to compel landowners to be present and indicate their boundaries; many owners did not live in the villages where their lands were

situated and their representatives, usually their tenants, had frequently an interest in giving incorrect information.

The very elementary educational equipment of the surveyors necessitated subdividing the work so that a man could be quickly taught the amount of surveying which it was necessary for him to know, and at the same time the checking and control should be made as efficient as possible. This was not attained at once, and until a network of triangulation existed and an independent Computation Office under skilled mathematicians had been formed, the control was insufficient. In 1899 these two indispensable safeguards were first introduced, and as they rapidly improved in efficiency, confidence was established and increasing of staff by surveyors who had had but a few months' training was not as risky as it might appear.

The technical methods were not taken from any one country or system, but were such as appeared suitable to the special conditions of the work, viz., a rapid and accurate survey of a level, open, agricultural country which was highly cultivated, by a staff having elementary technical knowledge, and trained, controlled, and supervized by a few competent inspectors. In Chapters X to XVIII, where the present survey is described, the methods of work are set forth in detail together with the reasons for adopting them and the results obtained from them. As has already been pointed out, time had to be considered first in consequence of the limit being fixed for the date by which the re-assessment was to be completed. As soon as the whole country had been mapped and the land-registers sent in, methods were modified so as to improve both the accuracy and the control in those respects in which hitherto the urgent necessity for rapid work had rendered a compromise to some extent unavoidable. I have indicated at each stage of the work the amount of such concession, which was always kept within the lowest limits possible, and in no case was sufficient to affect the primary object of the work, viz., the correct determination of the area and position of each landowner's property.

It is not claimed that this system of surveying was of a high educational value in forming surveyors competent to deal with any case that might arise, but it was the only practicable means of carrying out the detailed survey of this large area with satisfactory precision in the extremely short space of time at disposal; since this has now been accomplished, arrangements have been made for a more thorough and

systematic training of surveyors. What it did do was to produce a sufficient supply of surveyors competent to execute a single branch of the work efficiently; each one did work which directly or indirectly controlled that of another, so that the whole procedure consisted in a number of operations simplified as far as possible, each being checked by another operation independent of it.

Egypt has gone through the same experience as many other countries in making a series of experiments in surveying, with varying success. In 1823 Mohammed Ali Pasha caused about sixty villages in Sharqia province to be surveyed by Egyptian surveyors under the Italian engineer Masi, but nothing more came of it; the elaborate geodetic instruments ordered by Said Pasha were received, but were never used in a general survey; the cadastre of 1878 adopted methods which were too elementary to furnish a sufficient control upon the detailed measurements of so large an area. In 1892, State lands alone were being located and mapped, so that no elaborate system was necessary, but as the work advanced it appeared desirable to extend its scope and to undertake the re-assessment of the land-tax which was so urgently needed. In 1898, therefore, when the Survey Department was formed by the fusion of the State Lands, or, as it had by then become, the Revenue Survey, the Hydrographical Survey, the Map Drawing Office of the Ministry of Public Works, and the Geological Survey, the question again arose of deciding upon the system to be followed.

The logical method is certainly to commence with a triangulation of the highest precision, and to follow this by triangles of shorter sides and more moderate accuracy until sufficient points have been determined to control the field measurements made with the chain. It is not often that this counsel of perfection can be adopted, since it usually happens that other considerations are of greater weight, or have for the time being greater influence. Even if the most technically correct scheme of work will provide the result at a much lower total cost than another in which continually improving methods are adopted, necessitating subsequent revision of much that was done at first, still the value to a rapidly developing country of maps of even a fair accuracy is so great that it may become necessary to sacrifice some economy and accuracy in the technical work in order to supply maps at the earliest possible date and so meet the urgent requirements of the community. But nothing should be allowed to interfere with the employ-

ment of a triangulation network of sufficient accuracy to control the detail survey adequately, and to prevent errors from accumulating to an amount which would be appreciable. This has been very conspicuously the case in Egypt, where the maps were required at once in order to proceed forthwith to the re-assessment of the land-tax. Under these circumstances the only practicable method was to push on triangulation of the second and third order * as rapidly as possible, and to introduce improved methods as opportunity offered until the standard of work reached that which was necessary for the efficient control of a cadastral survey on the scale of 1 : 2,500; in practice, this attempt was so far successful that after 1898 only one province, Menufia, was surveyed without triangulation. In Giza province the triangulation was moderate in quality, in the Fayum it was considerably better and, indeed, fully adequate for the work required of it; after this, all other provinces have had a thoroughly satisfactory triangulation of a high quality.

The present survey is the first that has been carried out in Egypt on both a fiscal and topographical basis for the whole country. Although for some fifty centuries and more the cultivable lands of Egypt have been measured and recorded, it is only now that the registers in which this is done have been supplemented by a complete series of maps on which the shape of each property is shown, and its position with respect to other properties indicated. Formerly, it was considered sufficient to measure and record the area occupied by each landowner, but under this system land might be recorded more than once if the measurements took place at different times or were repeated; a landowner who had encroached on his neighbour's property might on re-measurement be credited with an area of land which was already inscribed under his neighbour's name, and the difference would thus appear twice if there was no plan showing the boundaries of the properties.

Numerous surveys have been made in which lands have been measured up and registered, beginning with those of Ancient Egypt, which are referred to in the inscriptions of that time, and ending with that carried out in the reign of Said Pasha, 1853–1859, in the last century, but the present survey is the only one which has been com-

* See Chapter XIV.

pleted topographically, by preparing maps on a large scale on which every holding is shown. It was preceded by the Cadastral Survey, which was commenced in 1878, and was intended to record both on maps and in registers the cultivable land of the country according to individual holdings, but the rigid economy which had to be exercised in 1883 reduced the annual expenditure on this work, and in 1888 the survey was finally suppressed when only between a sixth and a seventh of the country had been completed. It was not until four years later that work was resumed, at first on a small scale, but the annual out-turn gradually increased, and reached in 1903 1,000,000 feddans, which were surveyed on the scale of 1 : 2,500, the maps being printed and published on the same scale.

The various stages by which a cadastral survey of the accuracy demanded by modern requirements was reached may be seen from the following table, in which the principal land-marks in the steady advance from the methods which had sufficed for several thousands of years to those of modern times are recorded :—

1813-1822—The Cadastre was carried out by Muallim Ghali and M. Masi ; 60 villages in Sharqia province were mapped.

1853—The Cadastre of Bahgat Pasha.

1858—A base-measuring apparatus was ordered from Brünner, of Paris.

1861—A topographical survey of Egypt was made under Mahmud Pasha el Falaki.

1878-1888—The cadastral survey of portions of Beheira, Gharbia, Menufia, Qaliubia, and the Fayum provinces was executed.

1892—The commencement of a survey of State lands.

1895—The appointment of commissions to assess the rental value of the land ; the commencement of a revenue survey.

1898—The formation of the Survey Department to carry out a cadastral survey.

1907—The completion of the cadastral survey and the re-assessment of the land-tax of the cultivable lands of Egypt, all the maps being printed and published at first on the scale of 1 : 4,000 and later on the scale of 1 : 2,500.

Surveying is the application of physical measurement to the earth's surface and it furnishes the basis for the discussion of it ; on the one hand, therefore, precision of measurement, the elimination of errors of observation and similar points demand attention ; on the other, the nature of the region measured and the purpose for which the results are required must be borne in mind. Superfluous accuracy

may lead to as profitless an expenditure as attempting the survey of a large area without a sufficient means of controlling and eliminating the errors which must occur, so that a proper adaptation of means available to attain the end in view is essential to an economical scheme of work.

To sketch in broad outlines the profession of the land surveyor at various periods from the ancient Egyptian times down to the present day is both of interest and of practical importance, but information is scarce, and many gaps in the account prevent us from doing this at all completely; enough information, however, exists to show very strikingly how the geographical conditions of the Nile Valley have controlled surveying methods. With all our advantages to-day, our accurately divided circles for angular measurement, our telescopes furnished with micrometers for accurate pointing and measurement, our various methods for eliminating the errors produced by the expansion and contraction of our standards of length—with all these, when we come to the detailed measurement of small holdings we meet the same difficulties that our predecessors encountered 5,000 years ago. And in this part of the subject the improvements, though important, are not very numerous, being mostly in the computation of the areas, and in considering angles other than right angles. Where the great advances have been made is in measuring certain selected distances with high precision, and then, by accurate angular measurement, determining the relative positions of numerous points within a certain ascertainable amount of error. Within any area defined by any three or more such points we can control the detailed measurements, and thus prevent the accumulation of errors; moreover, all parts of the country are measured with reference to the same standard, and consequently the inconvenience and uncertainty which are caused by units varying in size in different parts of the country are avoided.

Though there are only two instances known of the cartographical treatment of land in ancient Egypt, the registration of the size, location, and ownership of holdings dates from very early times. Delimitations of boundaries are mentioned in inscriptions of the twelfth dynasty (1900 B.C.), lawsuits, in which records of ownership are produced from the State archives, are known to us in the nineteenth dynasty (1300 B.C.) and scenes of land-measurers at their work in the fields are reproduced on the walls of some of the Theban tombs, while statues of chief land-measurers have been preserved (see Plates I to III).

These examples of the procedure followed in ancient Egypt are full of interest to us at the present time, for in them we can see the origin of many customs which are still in use or have only recently begun to wane. A system of computation identical with that employed in about 2000 B.C. is still in use, not only in the villages by the local measurer, but also in provincial offices where staff of the old type still remain.

Any account of the present survey and its results may, therefore, be fitly supplemented by such information as is available concerning the measurement of land in Egypt in ancient, medieval, and modern times, which will lead up to the present methods, and may indicate the directions in which further improvements may be sought. Before, however, we study the measurements which have for their object the record of man's agricultural development of the fertile lands in the Nile Valley, it is necessary to go back a stage further in order to take account of the geographical conditions which not only render this region especially suited for agriculture, but also determine the general conditions to which man has adapted himself, and amid which he has evolved the system of land tenure which it has been the object of the surveyor in each successive age to record with more or less accuracy according to the intellectual standard of his time.

The geographical conditions which prevail in the Nile Valley are set forth at some length, for they are to a great extent peculiar to the country, though other countries furnish cases which are similar in some respects and to a certain degree. From this subject we pass to that of the units of length and area which have been employed at various times to define the size, shape and position of land property. Those of ancient Egypt remained in use until the eighth century our era, when others of Syrian origin replaced them with remarkable rapidity, to remain in use until the present time, when metric measures are daily becoming more familiar.

A brief account of land-surveying in past ages is given in Chapter IV, since the customs of the present time have their origin in the conditions of the past, and not a few of those of to-day persist because the present system, devised for a special purpose, does not yet fully meet the convenience of the individual cultivator. This account stops at the end of the eighteenth century, since the Cadastre of 1813–1822 ordered by Mohammed Ali Pasha marks the commencement of modern and more scientific methods.

The question of the classification of land in Egypt (Chapter V), is one which would occupy a volume by itself, but here it is only discussed sufficiently to indicate the points of importance to the surveyor ; for when representing on his maps or in his measurement book the properties of the landowners, he has had to take into account the forms of tenure, and the classification of the land in order that the taxes might be collected, the transfer of property recorded, and the lands of the State administered.

The various essays in land-measurement and surveying between 1800 and 1877 are recounted in Chapter VI, but the material available is scanty and the methods of work are but imperfectly recorded.

The Cadastre of 1878 (Chapter VII) was the first which definitely proposed to register and map the whole of the landed property in Egypt, and though it came to an end in 1888, the necessity of such a work had been fully recognized and the location and measurement of the State lands was instituted in 1891 (Chapter IX) which developed into the cadastral survey of the present time, of which the methods and results are set forth in detail in the later chapters (X–XVIII).

So far as possible, terms in use locally have been avoided, but in a few cases their employment has been necessary ; besides the explanation given in the text where they are first used, their meaning is also given in the glossary at the end of this volume.*

The Inspectors of the Survey Department have rendered much assistance in the preparation of this report, thereby greatly facilitating its production. Some have also contributed the results of their knowledge and experience in special sections of the work and these are acknowledged in the subsequent chapters. Without such help it would have been very difficult to represent adequately the detailed methods employed in executing so many and various operations in land-measurement.

* Appendix III.

CHAPTER II.

The Geographical Conditions.

The valley of the Nile in Egypt occupies a narrow belt of country extending for some 900 kilometres from south to north, from lat. 22° N. at Wadi Halfa to lat. 30° N. at Cairo; in breadth it varies from a few hundred metres wide in Nubia to 15–20 kilometres in the provinces of Assiut and Girga in Upper Egypt. Thus it occupies a narrow trough, on either side of which lies the desert plateau, sometimes sloping gradually down to the valley but more often terminating in steep cliffs which rise to heights of from 200 to 300 metres above it. Below Cairo begins the Delta, a triangular flat tract of country sloping very gently to the sea at the average rate of 0·1 metre in a kilometre; the side of this triangle measures about 170 kilometres, while its base, formed by the Mediterranean Sea, is 250 kilometres long, so that its total area amounts to about 23,900 square kilometres (see Plan I). Of this, 3,180 square kilometres are still occupied by the shallow lakes of Mariut, Edku, Borollos and Manzala, while formerly a much larger area was occupied by these and other smaller sheets of water. In the province of Beheira alone the area occupied by lagoons and flooded marsh has been reduced from 480 to 235 square kilometres between 1894 and 1904 by the drainage works carried out by the Irrigation Service.

In more remote times, as we shall see later, vast tracts of marsh formed a predominant feature of the Delta lands before the annual deposit of mud had raised the level sufficiently for reclamation to extend far from the banks of the river arms and the lesser branches.

The Delta and the Valley include all the cultivable lands which comprise a portion only of the whole region. Much land on the northern margin of the Delta is still too salt or too water-logged to be suitable for agriculture, portions are still occupied by marshes or lakes, while in the valley the desert margin is usually situated at too high a level for the silt-laden water of the flood to flow on to it even by the aid of long canals. The maximum cultivable area is therefore limited by the height to which the water of the river can be economi-

cally raised. It has been assumed that in earlier times the cultivable area was much larger than it now is, but this cannot have been the case in the valley, where throughout the historic period the river bed and the flood plains have been slowly rising as the river-silt was deposited year by year. In the Fayum towns flourished in the Greek period above the present margin of the cultivation, since the lake level was much higher and the lower portions of the province were then submerged. In the Delta, ancient mounds in the northern portion mark the sites of towns where a considerable population once flourished; the tombs of Roman date near Alexandria afford evidence that there has been a downward movement of the land here which will have interfered with the water-supply and water-logged the soil, thereby making the region uninhabitable until modern engineering skill has succeeded in reclaiming it from its present condition.

This Valley and Delta are situated in a region in which the climatic conditions are strongly marked and their effect has been great on the plant and animal life inhabiting it. Egypt lies in a region of high atmospheric pressure from which the air streams southward towards the equatorial belt of low pressure; dry to start with, its relative humidity is much reduced as it blows over the heated deserts, where there are no hill ranges of sufficient height to cause local precipitation, so that the climate of Egypt is practically rainless. At Cairo an average amount of 25 millimetres of rain falls annually, but south of this an occasional storm alone is recorded. In the Delta the yearly total of rain increases to 200 millimetres at Alexandria and 100 millimetres at Port Said, but the decrease inland is rapid, and nowhere, except on the coast belt near Alexandria, is the rainfall of any practical value to agriculture. The cultivator depends wholly on the Nile to supply him with the water necessary for raising his crops and the remarkable regularity of its rise and fall must at an early date have established the agricultural methods which have been employed almost without change down to the present time.

The monsoon of East Africa reaches the Abyssinian tableland in June and the rains there become heavy in July and August, diminishing rapidly in September as the rain-belt moves southwards again towards the equator. The direct consequence of these rains is the rise of the waters of the Blue Nile flood, which hold back the waters of the White Nile on account of its low slope, so that the Blue Nile alone supplies the

Nile flood, on which Egypt depends. The river begins to rise at Aswan early in June, reaches its maximum at the end of the first week in September and then falls rapidly ; at Cairo the rise does not usually begin till July and the maximum height is reached at the beginning of October. By the end of the year the supply of the Blue Nile becomes small and from that time onwards the White Nile is the main factor in furnishing the low-stage supply of water to Egypt, but if the assistance given by the waters of the Sobat and Blue Nile should then be exceptionally small, the supply is reduced to that which the Bahr el Jebel, Bahr el Zaraf, and Bahr el Ghazal furnish, an amount quite insufficient for the needs of Egypt.

The relation of the supply of water furnished by the Blue Nile to that of the White Nile at different seasons of the year can be readily understood from Fig. 1, in which the distance between each horizontal line represents a discharge of 1,000 cubic metres of water per second.

The harvest is in April or May, and, from then until the next flood inundates the land, the soil is parched and dry except on the river banks, or where a well enables the cultivator to water a small patch. Agriculture is, therefore, wholly dependent on the river and its annual flood for the succession of operations from seed-time to harvest, and this has been the case from the earliest times when the mud from the high land of Abyssinia had

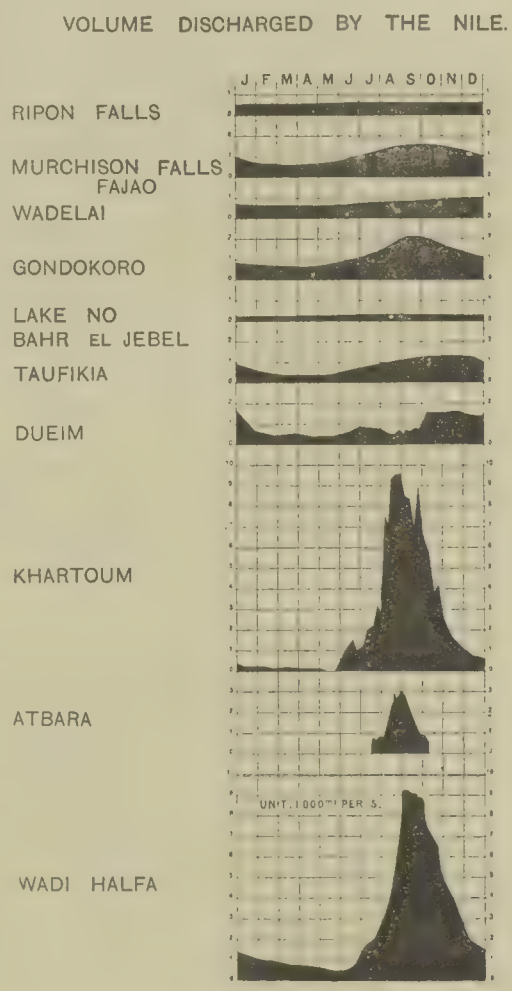

Fig. 1.

been deposited in sufficient quantity to form a cultivable soil on which the early inhabitant of the valley could settle and support himself.

But even though the regularity is so remarkable, there is a certain difference between floods of different years, and the agriculture is dependent, in the absence of rainfall, on an annual river-flood which does not vary in volume from year to year by more than 30 per cent. above and below the mean value except in very exceptional years.* In early times the river must have inundated the greater part of the flood-plains below Aswan and the Delta also, until man began to control the waters of the river by means of banks and canals, and to lead them wherever they were needed by his crops. Thus he developed a primitive form of basin irrigation in which canals led the silt-bearing waters of the flood on to the cultivated lands, where they were retained by banks until the mud had been deposited and the river had fallen sufficiently for the water to drain back into it again. In this way an addition of virgin soil was annually made to a rich flood-plain which was never deeply ploughed, and this regular addition maintained its high fertility. Sown on the wet mud left by the water when it was drained off, the crops grew luxuriantly, drawing the moisture which they required from the ground, which was saturated by the inundation, and receiving no additional supply either by rainfall or artificial irrigation.

Looking back to the later geological times when the Red Sea had been formed and the Nile Valley outlined as a line of fracture in the limestone plateau, we are led by such evidence as is available to the view that in prehistoric times the depression, which is to-day the Nile Valley, was in all probability occupied by a series of lakes, and in a somewhat more humid climate which may have then prevailed, forest and jungle-growth lined the edges of the valley and the lake margins. With the advent of the drainage water of the Abyssinian tableland, by whatever course of events this was brought about, the rich reddish-brown silt, the product of the disintegration of the basalt of Abyssinia, was deposited to form the flood plains of the Nile as it flowed between the steep limestone walls of rock on either side.

As in the case of all rivers carrying much material in suspension, the flood-plains were built up more quickly near the bank of the river,

* LYONS, "Physiography of the Nile." Cairo, 1906. Chap. X.

where the velocity of the flooding waters was first checked and their load deposited. On the confines of the valley there remained low-lying stretches in which at first were large lagoons, which in time became swamps, and finally, as deposition continued, were represented by a few isolated depressions, probably connected by an arm of the river flowing with a meandering course parallel to the main stream. As layer upon layer of mud and fine sand was laid down, the flood plains would be gradually raised, and the swinging of the main channel from side to side of the valley resulted in the formation of a level plain though during the process loops of the river which had been cut off from the main stream long existed as narrow ponds and lakes.

The earliest human settlements of which we have knowledge at present were inhabited by fishers and hunters rather than by cultivators. In their graves are stone weapons of a highly-developed type, while copper occurs as yet in the form of ornaments only; on their pottery are the representations of elephants, giraffes, ostriches, and many species of antelope, all of which must have been well known to them and frequently encountered. But there seems to be no ground for assuming difference of climate at this late period to account for their occurrence, but rather that the geographical conditions existing in the valley at this time were such that but a portion was cultivated by its inhabitants and that a wide extent consisted of such a labyrinth of marsh, lagoon and coarse vegetation as would provide suitable haunts for such a fauna. The present condition of the Bahr el Jebel valley may be quoted as illustrative of this to some extent. It would be along the desert margin at the edge of the flood-plain that these conditions would prevail longest; here, the low-lying land would yearly remain filled with the waters of the flood till long after the river had fallen, and marsh vegetation would flourish luxuriantly. * A belt of such country must still have occupied the western side of the valley in early historic times, and we may see evidence of this in the tomb scenes of the Old Empire at Saqqara, Lisht, Meidum, and, further south, as at Beni Suef and Assiut, in which hunting animals and killing of the hippopotamus and crocodile and the fishing in the lagoons, form the principal recreations of the great nobles of Ancient Egypt.

* Cf. HERODOTUS, Bk. II, 4.

As time went on, deposition took place on the banks of the main stream and its principal branches, so that the second stage in the occupation of the valley consisted of the founding of towns and villages on the higher banks, cultivation extending to these portions, and to the land which sloped down to the marshes as the inundated area dried up by evaporation or by being slowly drained by the river branches which flowed through these low lands. These marshes were gradually filled up by the deposit of mud from the flood-waters, and, in the New Empire, we no longer hear of hunting in the marshes, fishing and snaring birds. In place of these forms of sport we hear of wild cattle being pursued on the western margin of the Delta, and of gazelle and antelopes being hunted; but the marshes have greatly diminished and no longer form a principal feature of the valley. It may be reasonably concluded that the wild fauna which is mentioned in the inscriptions lived on the margin of the desert and found their food and water in the long belts of unreclaimed land which must have existed for a considerable period after the silting up of the great marshes commenced.

Though all this took place at a remote period of history, many centuries were occupied in this natural reclamation of the valley, and even to-day we may see the signs of the former state of things.

The canal known as the Bahr Sohagia (Plan II) which now leaves the Nile at Sohag, was no doubt at one time the main stream of the Nile for a short distance northwards of this town; when the eastern arm became the more important, the western dwindled to a branch which, when no longer able to reunite with the main river, flowed to the lower-lying land near the edge of the flood-plain. The continuous water-channel of to-day is almost certainly a river branch aided by artificial adaptation of the pools, river arms, etc., which were left after the marshes had been brought gradually under cultivation, and it now serves to carry the waters of the main stream to the village lands under the western cliffs where, after a course of 165 kilometres, it ends near the village of Meir in a group of irregularly-shaped pieces of water which we can hardly be mistaken in considering as the last remnant of an ancient marsh.

Immediately beyond the termination of the Bahr Sohagia, the other great natural stream of Upper Egypt—the Bahr Yusef—leaves the main river and follows its meandering course along the western

edge of the flood-plain until it enters the depression of the Fayum at Lahun after flowing for a distance of 164 kilometres (Plan III). This portion of Egypt between the Nile and the Bahr Yusef has been recently converted from basin irrigation to perennial irrigation, and the new canals, banks, and drains so fill the maps with detail as to obscure the more ancient geographical features; still, the typical form of a natural stream is to be readily recognized in the Bahr Yusef even though man may from time to time have modified it to suit his requirements.

Even at the present time the Bahr Sohagia and the Bahr Yusef, which are now used as main supply canals in Upper Egypt, show by their position, by the absence of dykes along them and by their meandering courses, that they are really the river branches which flowed along the "bottoms" at the edge of the valley since they were unable to cut their way through the higher portion of the flood-plain which lay between them and the Nile. They are the last remnants of the belt of marshes and lagoons which in earlier times occupied the margin of the valley and were gradually reclaimed by the advancing cultivation as the Nile mud was annually deposited in them and the land raised to the level of the rest of the valley. Even now there is a gradual though slight fall of the land from the river to the desert edge, and the basin land which lies away from the river is lower than that which borders it (see Plan IV).

In consequence of this normal building up of the flood-plains by deposition from the silt-laden waters of the annual flood, perennial cultivation would first occur on the river banks while behind this belt would lie the lower part of the flood-plains, which would support a single crop, sown directly after the flood subsided and coming to maturity by utilizing the water retained in the soil without a further supply being furnished.

These low-lying or basin lands comprised, until quite recently, by far the larger portion of the lands of Upper Egypt, and it is only within the last few years, since the Aswan Reservoir has increased the low-stage supply of the river, that there has been sufficient water for the introduction of perennial irrigation in some of the provinces. The villages in these basin lands were situated on any rising patch of ground, probably in the first instance the bank of the main river, which in course of time swung away from it and left it in the open floor of the valley. As each generation built its mud-brick houses

on the ruins of those which had fallen, the village site rose more rapidly than the flood-plain itself, and thus it stood and still stands up above the waters of the inundation as a dwelling-place for the inhabitants and a refuge for their cattle when the fields are flooded.

In this manner villages would have arisen as cultivable land increased and the marshes diminished as a result of long-continued deposition by the silt-bearing waters of the Nile flood.

In the Delta the process of natural reclamation proceeded on similar but not identical lines. Here a number of water channels took the place of the single stream; some were the larger and more important, but even these, by constant bifurcation, supplied smaller branch channels and became reduced in size themselves. Cross channels connected the different arms of the river and the usual state of unstable equilibrium common to all deltas caused now one channel and now another to become the more important. The larger river-arms would build up their banks by deposition of silt from the muddy waters of the flood which were flowing to the sea, while the rich growth of aquatic plants in the smaller channels and backwaters would have prevented the entrance of the flood water and so hindered deposition in the intervening areas. On the banks of the main channels, therefore, settlements would first be made and cultivation would gradually spread down the gentle slope leading from the channel-bank to a point at which the ground began to rise again to the next channel. Here, too, the range of the water-level is much less than in the valley and thus, as the cultivable area of the Delta increased by long-continued deposition, the conditions approached somewhat more closely to those of perennial irrigation than among the basin lands of Upper Egypt.

Between the larger supply-channels there long remained a belt of marsh which received the surplus water from the sloping land on either side, and traces of these are to be seen not only in the maps of the Delta before the increased cultivation of cotton caused the reclamation of uncultivated land on a large scale, but even to-day, when lands which bear the higher rates of land-tax are grouped along the main streams and the ancient natural arms which are now main canals, while the lower rates are confined to the intervening areas which are now being reclaimed by drainage, and to the desert margins.*

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* Compare Sheet No. 30 of the Map of Egypt, scale, 1 : 100,000, prepared by the French Expedition of 1798.

At all times, the Delta contained a much more tangled network of water-channels than the valley where the slope was greater, and even to-day we may easily recognize on the maps the twisting and irregular course of the natural streams, which are in strongly marked contrast to the straight reaches of the modern canals. The main arms of the old Delta are in some cases distinguished to-day by the name " bahr " (river) by which they are differentiated from the artificially-constructed or maintained canals, but they are only large and self-evident examples of the numberless instances which exist throughout the Delta to show that the old natural channels, more or less modified, form the greater portion of the elaborate canalization of to-day (Plan V).

Many channels were silted up as time went on, and soon became indistinguishable from the rest of the land, but on the cadastral maps their course may often still be traced by the lines of small holdings which follow the ancient river-bed, since they were laid out much later than the plots which occupied the banks (see Plan VII). This is not peculiar to Egypt, but the same may be seen in any delta or alluvial plain that has been cadastrally surveyed.

The central portion of the Delta is densely populated and highly cultivated, so that we may expect the land to be greatly subdivided for some distance to the north of Cairo, and it is, in fact, not until we get to the northern portion or on the desert margin that we meet with open tracts of land of poor quality, where the holdings are large, since only landowners with capital at their disposal can afford to carry out the necessary works of reclamation.

The evidence of the ancient nilometers * of Egypt tells us that the valley and the Delta have changed much since they first became suitable for human settlements. The silt brought down annually by the river flood was for the most part carried out to sea as it is to-day, to be deposited along the seaward margin of the Delta, and to be carried eastwards along the coast by marine currents; but a portion was deposited on the flood-plains of the valley and on the bed of the river itself as the current slackened, so that the ultimate result has been a

* Borchardt, "Nilmesser und Nilstandmarken," Abhandl. d. königl. preuss. Akad., Berlin, 1906.

secular rise of both plain and river-bed which appears to amount on the average to about 10 or 11 centimetres per century. Thus the lands which were cultivated in the Old Empire are now covered by two metres of Nile mud, and the river-channel of to-day is often in a very different part of the valley to that which it once occupied. The well at Edfu temple in which the nilometer scale is cut is now far from the river, though it must formerly have been close to it; the division of the village of Badreshein, in the province of Giza, which is still known as the "Hod of the Nilometer" is now some 1,600 metres from the river, but must once have been on its bank when the nilometer of Memphis was still in use. By slow erosion of its banks the river is continually shifting its bed, and the determination of such loss of land, as well as the measurement of that which was newly deposited, has always formed a part of the duties of the land-measurer; the procedure also for relieving such eroded land of tax and for distributing that which had been newly formed took shape at a very early period, and in a country where riparian lands formed so considerable a proportion of the whole, cases of this nature were a very frequent cause of dispute.

The remarkable regularity of the meteorological conditions and consequently of the river regimen has left its mark on the people and their customs. The deserts which bound the Nile Valley on the east and west, and the marshes of the Delta on the north cut off for many centuries the Egyptians from the influence of neighbouring nations, while the single route which led along the eastern side of the Delta into Asia was far from furnishing an easy or convenient line of communication. The Nile to the south was interrupted by the second and third cataracts and in this part of its course its valley plain is narrow and sparsely cultivated. All these factors assisted the Egyptians to keep themselves aloof from the nations which were nearest to them and made them more conservative in their customs. The result of such a development in an enclosed region, comparable in many respects with a mountain valley cut off from its neighbours by high ranges and difficult passes, was accentuated by the climatic and hydrographic conditions. A climate which was favourable to vegetable growth at all times of the year if water was obtainable, and an annual flood which occurred with the greatest regularity, seldom varying more than two or three weeks from the average date, has, from the earliest times,

caused an invariability in the field seasons which has reacted on the character of the people.

This unvarying cycle of their water-supply, of their agriculture, and consequently of their domestic life, combined with the freedom from immigration which the deserts and the Delta swamps ensured, laid the foundations of that conservatism of custom and character for which the Egyptians were noted in ancient times. Nor has this greatly changed, and there exist to-day in every phase of Egyptian life traits which have come down from early times almost unaltered; the examples furnished by the science of land-measurement are as striking as any that we know. The inundated flood-plains were sown immediately the water had subsided—as soon as the property boundaries could be recognized in the wet mud—after which no further labour was necessary until harvest. On lands to which the canals led water, a part of each holding had to abut upon the canal or a subsidiary distributing channel, since in the absence of all rainfall the river water alone made the growth of crops possible. The cultivator whose supply of water had to pass through a neighbour's land before reaching his own was at the mercy of the latter; and consequently we find as a general rule that plots of land lie at right angles to the direction of the supply-channel. In the earliest times these were branches of the main stream, bends which had been cut off from it, or parallel channels flowing in the lower lands at the sides of the flood-plains, but as civilization advanced, canals were made and the older natural channels were either modified or utilized in the general scheme of water distribution.

In basin lands which received an annual flooding and were not supplied with water throughout the year by canals, plots are arranged variously without reference to water-supply, but they follow instead certain main lines which have been found convenient for dividing up the land (see Plan VIII).

Of late years the introduction of perennial irrigation throughout a large part of the country has introduced modified conditions which have somewhat simplified the surveyor's work. Instead of a few large supply-canals, there is a network of small canals, subsidiary water-channels, and even little runnels of water which irrigate each holding. Since the land is no longer inundated annually, but receives water throughout the year, field boundaries have not now to be laid down each time that a crop is sown, but the small water-channels have con-

siderable permanency, and, though they are not so distinctive a topographical feature as hedges, still they divide up the land into parcels which do not vary annually, and they can, therefore, be usefully indicated on the map. In a country where it is as yet impracticable to oblige landowners to mark the boundaries of their properties in a permanent manner, even such features as these are of great assistance.

The long and narrow shape of the Nile Valley, lying very nearly north and south, may well be expected to have left its mark on the customs of its inhabitants. Towards the east and west, the directions to which the rising and setting of the heavenly bodies draw the attention of most primitive peoples, the Egyptian of the Nile Valley was greatly restricted; after a few hours' journey at the most, he reached the limits of the cultivated land, and beyond this rose usually the limestone cliffs which could only be ascended here and there by steep footpaths. To the northward and the southward, on the other hand, lay the towns and villages of his countrymen, while the river furnished a convenient line of communication and a cheap means of transport; north and downstream, south and upstream, were for him, therefore, synonymous, and in ancient times as at the present day, the cardinal points of the horizon were more often used in indicating the position of objects than in countries where the direction of the natural features are less sharply defined. But, at one portion of its course in Upper Egypt, between Qena and Baliana, the river turns sharply westwards and even flows in some of its bends from north to south for a short distance, so that the conventional use of up- and downstream as the equivalent of south and north no longer holds good. Nevertheless, they were and still are so used, a custom which greatly adds to the difficulty of locating land from the descriptions given in the old title-deeds of this part of the country, where the northern and southern boundaries are in consequence reversed by adhering to this ancient formula. Property limits are not alone concerned in this, for near Dishna, in Qena province, the village of Fau Bahari (the northern) lies to the south of Fau Qibli (the southern), being downstream of it, and the same relation holds between El Halfaia Qibli and El Halfaia Bahari on the other bank of the river; similarly, the southern village of Naga el Nizeila lies to the north of the middle one (Wustani) while the northern one no longer exists, removed perhaps by the encroachment of the river bend (see Plan IX).

The geographical conditions, then, with which the surveyor has to deal are of a very special character. The rainless climate renders cultivation impossible beyond the reach of the waters of the river; the alluvial flood-plains are bounded by desert cliffs or the more gentle slopes of the desert margin, but both are equally out of reach of the river water except by pumping it at a heavy cost. Thus work is confined to a narrow belt of land and the large triangles of continental surveys are usually impracticable. The alluvial character of the flood-plains and Delta, unbroken by higher ground, simplifies work by removing all questions relating to slope and relative height, but at the same time favourable points for triangulation are not always easy to find, and in many parts of the Delta trees greatly interrupt the view.

The fertility of a country which enjoys a climate favourable to plant growth throughout the year is limited only by the quality of the soil and the water-supply available, and consequently Egypt has always been highly cultivated in the neighbourhood of the river and its branches. Carrying in some parts two and even more crops a year and receiving annually a supply of fresh virgin soil on the inundated land in the form of the fine silt deposited by the flood water, this land has always been able to support a dense population and consequently the individual holdings are small. All the available ground being required for crops, grazing lands do not exist; and hedges, fences and all similar boundary marks are absent. The surveyor has, therefore, to deal with a country which is practically level; which is carrying crops whenever and wherever the necessary water is obtainable; which is much subdivided, being owned in very small portions; of which large areas are annually inundated and thus cannot be surveyed during four months of the year; where property boundaries are not permanently marked; and where erosion and deposition by the waters of the annual flood cause considerable changes in the riparian lands. At the same time soil of such richness and fertility is of much value, and accuracy of measurement is essential. Title-deeds are and have long been made out to single sahms (7·29 square metres), though certainly the measurements on which they were based were of very moderate precision.

Not only are the flood-plains of the valley cultivated, but also the sloping banks of the river, and the low islands and sandbanks which are uncovered as the river falls.

This class of land has to be measured and divided up annually, since the area varies with the water-level and with the results of the erosion and deposition that the river has effected. The annual measurement of such land is carried out by local officials, but during the cadastral survey this class of flooded lands caused great inconvenience, for the urgent necessity for completing the survey of a province by a given date sometimes led to the registers being prepared before the river had sunk to its lowest level, and the lands which were thus left unmeasured had to be surveyed subsequently.

The crops, too, very largely determine the seasons when land can be surveyed, for the "durra" crop in October and November and the sugar-cane during December and January form a complete obstacle to either traversing with the theodolite or land-measuring with the chain. Both of these grow three and four metres high and form dense masses of vegetation which occupy a very considerable area. It is also both undesirable and inconvenient to work in areas which are planted with cotton when the plants are well grown, that is at the end of the summer.

In all surveying, or making measurements of portions of the earth's surface, the geographical conditions must be the predominant factor in determining the most suitable method. The difficulties which the measurement of land in Egypt presented to the ancient Egyptians 5,000 and more years ago differed but little from those which were dealt with by the surveyors of Græco-Roman times, whose results are preserved in the papyri from the Fayum, Bahnessa and other places; by the surveyors after the Arab conquest, and in the later times when modern engineering came to the assistance of more ancient methods of irrigation; finally, we are endeavouring to deal with identical problems to-day.

The geographical factors which have just been recapitulated have determined once for all a state of things which the surveyor must, consciously or unconsciously, take into account if his work is to be satisfactory, and they may be summarized as:–a narrow belt of country where holdings are unusually small and highly cultivated; where the land is of much value as being capable of supporting a dense population, but only in so far as the water of the Nile is readily accessible.

The method of land-measurement once decided upon in early times would be rapidly improved and developed by constant practice,

since the land had to be re-measured annually after the waters of the inundation had receded ; for, as already explained, the whole country was at first under a more or less primitive form of basin irrigation, and only the banks of the river would be sufficiently high to be cultivated during the flood season.

From very early times Egypt was divided into provinces or districts for purposes of administration, and within these the village was the unit. References exist to the boundaries of these districts, and in laying out those of his new city near Tel el Amarna, Ikhnaton (B.C. 1580) describes the numerous boundary stones which he caused to be erected (see page 50).

The division of the country into the present provinces (Mudirias) is not of ancient date. The village, however, is the real geographical unit, and the majority of villages in Egypt are certainly of great antiquity ; their names have been modified as the language of the population changed, but the village site remained the same. Of the permanence of their boundaries nothing can be said, since no maps more than twenty-five years old exist on which they are shown, but there is undoubtedly much of historic interest to be recovered by anyone who will work on the maps recently published when studying the past history of the country.

The land is very unequally divided up into villages which vary in size from a few tens of feddans up to several thousands. In each group of village lands which are recorded in a single land-register there may be numerous hamlets, and one of these is taken as giving its name to the village as regarded from a revenue-producing point of view. Where villages are very large they are frequently subdivided for purposes of public security and control by the Ministry of the Interior, but this affects only the hamlets and their inhabitants, who are grouped under the authority of different sheikhs ; the lands are not delimited according as they are owned by the inhabitants of the hamlets, but remain included in the total area of the principal village.

On the whole the village boundaries appear to have been fairly stable in past years and the boundaries are indicated without much difficulty, although at the time of survey a village omda will sometimes try to have a tract included with the limits of his village in order to increase the range of his authority ; but usually cases of difficulty only arise when the lands of two villages are much intermixed.

From time to time in the past proprietors who owned land in different villages found it convenient to pay their taxes and settle similar business in a single village, so that a dweller in one village would arrange that the plots he owned in villages B, C and D should be included in the village register of A where he probably lived. So long as taxes were collected and questions investigated by the aid of registers alone the matter was not of so much importance, but when maps were prepared the inconvenience of having plots of land belonging to one village scattered throughout dozens of surrounding villages, sometimes many kilometres away, became very apparent. During the present survey, therefore, such isolated portions of land have been included in the register of the village in which they lay. Work was often much delayed by the necessity of doing this, since a village could not be completed until all surrounding villages in which portions of its land lay had been mapped in order to ensure the correct area being deducted from the one and added to the other.

Another difficulty which arose, especially in Upper Egypt, was due to the lands of a village being owned partly by the Moslem and partly by the Coptic inhabitants. This has been a fruitful source of disagreement in the past, and the matter had sometimes been settled by compiling two registers, in one of which the lands of the Moslem proprietors were recorded, and in the other those of the Copts. Different village names may be employed for each, as for instance in the district of Simbellawein where the Moslem portion of a village was called El Balamun, the Coptic portion being known as Kafr Yusef Awad. These portions were not divided by any boundary, whether defined or undefined, but individual plots were intermixed throughout the village, though they were sometimes sorted out into two different registers (see Plan X). Such an arrangement was highly inconvenient for the re-assessment of land-tax but in most cases a definite boundary was only agreed upon after much discussion.

Village areas differ widely in their shape, which is controlled by many factors, and it is probable that careful study would throw much light on the causes which have contributed to form them and would indicate which of these have been of especial importance. In the southern portion of the valley, the province of Aswan, where the cultivable strip on either bank is narrow, the inhabitants have settled on the river bank and then cultivated the alluvial plain towards the

desert. The width of this plain is often too small for any considerable development of irrigation canals and a single supply-channel which brings the silt-laden water of the flood to the lands away from the river is often all that exists. The village lands, therefore, stretch from river to desert, and when this belt is very narrow the village area extends for some distance along the bank in order to include sufficient land to support the inhabitants of the village (see Plan XI).

Even where the flood-plain is wider, as in the neighbourhood of Qus and Qift, the same development of boundaries may be seen, but beyond the village lands which abut upon the river bank there are a number of scattered hamlets situated near the limits of the plain, and cultivating large tracts of the poorer lands which are to be found there. Wells are very largely used by these villages on account of their distance from the river, for no perennial canals yet exist in this part of the valley (see Plan XII).

Further north, in the southern part of Girga province and in the portion of Qena which adjoins it, the lands of different villages interlace with each other in so remarkable a manner that it is difficult to believe that it is not due to some definite cause. The most probable explanation is that a landowner in one village obtained by purchase or inheritance a plot or plots in the next village and for his convenience arranged for their transfer to the register of his village. Thus the village boundary was altered and as most of the plots in the basin lands are long and narrow it gradually acquired the irregular form shown in the plan. The resulting boundaries (see Plan XIV) are most inconvenient in their irregularity, but strong opposition was offered by the inhabitants to all proposals for simplifying them.

In southern Girga, villages line the bank and the desert margin, while others are built in the middle of the plain, where they stand as islands during the inundation ; their lands are in rather elongated areas stretching from those of the riparian villages on the one hand to those of the desert edge on the other as though they had extended down the slope of the flood-plain towards the low-lying lands. In the great basin lands of north Girga and Assiut, the same kind of arrangement occurs of villages on the river bank and the desert edge with others at wider intervals on the flood-plain between. These latter are either arranged along the banks which divide the land into basins into which the flood waters flow, or stand isolated in the centre of a basin ; in this

case the village is usually a large one and not improbably one which was once on the bank of some river branch which has since disappeared; once established, it would be more convenient to enlarge an existing village than to commence another on land which was annually flooded (see Plan XIII).

Being a unit complete in itself for revenue purposes, each village had to be surveyed separately, since the village authorities and the inhabitants have to be constantly referred to, and it greatly simplified the work to prepare the maps by villages in the same way. This was always done up to 1900, but as soon as the triangulation was sufficiently advanced a series of map-sheets was prepared having continuous sheet lines, so that every sheet was full of detail and portions of several villages might appear on one sheet. This additional work was fully compensated for by the gain in accuracy, for not only were the maps more convenient for reference, but it ensured the common boundaries of the villages being carefully checked.

Coming to the smallest geographical unit, the holding or plot, we find in it several characteristics which are very intimately connected with the surveyor's work, and which necessitate special consideration. The first and most important of these is its size; the land is for the most part extremely subdivided, as the following table will show :—

Province.	Total No. of Plots.	Percentage of Plots.			Average size of plot in feddans.
		under 12 qirats or (0·21 hectare)	between 12 qirats and 5 feddans (0·21 to 2·1 hectares)	above 5 feddans (2·1 hectares)	
Beheira...	Under re-survey		—	—	—
Gharbia..	271,019	25	65	10	8·8
Menufia..	261,927	34	62	4	1·5
Qaliubia..	89,379	36	51	7	2·8
Daqahlia.	184,147	32	58	10	3·5
Giza ...	101,169	34	59	7	2·4
Fayum...	125,125	44	50	6	3·3
Beni Suef	132,008	44	50	6	1·9
Minia ...	123,534	38	51	11	3·7
Assiut ...	251,883	41	54	5	1·9
Girga ...	217,679	39	56	5	1·6
Qena ...	200,605	41	53	6	2·0
Aswan ...	38,739	40	50	10	2·7
Mean...		37	55	8	3·0

Besides this a considerable number of plots are owned by two or more persons in share but without any definite boundary between their respective portions having been agreed upon. In Sharqia, where such ownership in share was specially investigated, 43,000 out of 160,700 plots were found having two or more owners, who had certain proprietary rights over them. Further details are given in chapter XVII.

The shape of the holdings varies considerably, but the rectangular form or a close approximation to it far outnumbers the others. At times the ratio of length to breadth is as much as 300 or 400 to 1, but such extremely long and narrow plots are exceptional. They are not peculiar to this country, but are to be met with for instance in Northern Prussia. Their origin is readily accounted for; where supply canals lie far apart, large properties stretch from one to the other for facility of irrigation. When these properties are divided among heirs, strips of land of the full length of the property are formed and this process of subdivision will go on until the breadth of the holdings becomes so small that crops have to be sown and harvested in groups of several plots. A more successful or influential landowner may perhaps acquire many of these strips, thus re-constituting the large property which may again in time be subdivided in the same way as before. The necessity for access to a supply channel in this country, and perhaps to a drainage channel in Northern Europe, explains why the length of the holdings is maintained. In some parts of the country the plots are less commonly rectangular but are very irregular in shape, as in the Fayum where the comparatively steep fall of the ground from the Nile Valley to the Birket Qarun causes the watercourses to flow in the meandering form of natural streams rather than in the straight reaches of artificial canals, (Plan XXVII). In the poorer land of the northern delta irregular shapes are common, having originated either from cultivation having begun as isolated patches on the more favourable spots, or in other places having been determined by the winding water-channels of the low deltaic flats before scientific methods of reclamation had been introduced. Where these are being employed straight rectangular plots bounded by a regular system of supply and drainage channels predominate (Plan VI). The subdivision of the less regularly shaped plots has also produced numerous triangular pieces of land which are unsuited to the old methods employed for computing field areas.

CHAPTER III.

Units of Length and Area.

Herodotus speaks of Egypt as being the original home of land-measurement, in which the science of geometry was first developed by reason of the necessity for determining the property boundaries by re-measuring the land after the annual inundation had receded and determining how much the river had eroded.* It is hardly possible to say whether this statement is exact in the form in which it stands, but there can be little doubt that the fertile valleys of the Euphrates and the Nile were among the first in which an early civilization felt the need of some means of determining accurately the area of the cultivated land. This would arise as soon as the population had increased sufficiently to cultivate most of the land that was suitable for tilling, and, from the evidence which has been adduced in the last chapter, it appears as though but a portion of the present valley could have been so utilized at the beginning of the historic period, so that an increasing population would soon occupy the more fertile portions and the definition of boundaries would assume a practical importance sooner than in larger areas. Traces of man's culture are so well preserved in a rainless country that, if they are buried out of reach of the river flood, they may remain unharmed for thousands of years until brought to light by modern archæological investigations; it is to this circumstance that we owe our knowledge of the methods used by the earliest civilizations in dealing with the land they owned and cultivated. There is no reason to suppose that land-measurement did not exist in many another alluvial plain or valley in remote times, but the traces of it have disappeared, and at any rate the necessity for it would be greater where the area was limited and the population dense. Egypt, by its isolated position in the midst of trackless deserts, was peculiarly fitted for rapidly developing this science, since, in the first place, the area of cultivable land in the narrow valley was always limited by the desert and by the marshes of the river, and, secondly, free from immigration or invading tribes, the methods suited to the requirements of the case would be quickly

* Cf. Herodotus, Bk. II, 109.

evolved and then long retained without alteration. If the settlements of predynastic age which have been so much investigated of recent years are primarily those of a hunting, fishing and pastoral population, agriculture must have been extending and must already have attained a considerable development in the later part of this period, since we find it in the early historic dynasties to be the most important employment of the people ; the provision for ploughing, sowing and harvesting in the future life, which was made in tombs as early as 3000 B.C., indicates a very early date for the beginning of agriculture in the valley.

As soon as we meet with written records of this people we find that the principal unit of length, the cubit, together with its subdivisions, was already in use, for, on the Palermo Stone* are recorded not only the principal events of each year of each king's reign in the first four dynasties, but also the height of the Nile flood as measured annually on the scale of some nilometer. Not only whole cubits, but its subdivisions, the span, the palm, and the finger, were used, so that even at this remote time the system of measures was fully developed and must have been already long in use.

Both a long and a short cubit were employed in Egypt, besides the "upper arm" and these three stood to each other in the proportion of 7 : 6 : 5. As subdivisions of the cubit there were the "span," the "handsbreadth," and the "finger," this last being even subdivided as low as one-sixteenth. These subdivisions are derived from several inscribed examples of cubit rods which have been found in ancient tombs and a series of them has been described by Lepsius in a memoir on the subject.† He gives the following fractions of a cubit ‡ :—

			palms.		metre.
meh suten	or	royal cubit	= 7	=	0·525
meh net's	„	short cubit	= 6	=	0·450
remen	„	upper arm	= 5	=	0·375
t'eser			= 4	=	0·300
pet aa	„	great span	= $3\frac{1}{2}$	=	0·262
pet net's	„	small span	= 3	=	0·225
		handsbreadth	= $1\frac{1}{4}$	=	0·094
shep	„	palm	= 1	=	0·075
t'ba	„	digit	= $\frac{1}{4}$	=	0·019

* SCHÄFER. Abhandlungen d. königl. preuss. Akademie 1902 ;
NAVILLE. "Recueil de travaux archéologiques." 1903, p. 64.

† "Ueber die altägyptische Elle und ihre Eintheilung." Berlin, 1865.

‡ See also GRIFFITH, "Proc. Soc. Bib. Archæology theilung," 1892, p. 433 ff. for much information on Egyptian weights and measures.

In land-measurement the fractions of the cubit are not needed, but its length is important as the basis of the larger measures of length and of those of area. From the copies of the cubit which he described, Lepsius obtained a mean length of 0·525 metre, and Professor Flinders Petrie determined the length of the cubit on the rods to be 20·65 inches or 0·526 metre. Besides this source of information the length may also be derived from buildings which still exist and for which we have the dimensions stated in ancient Egyptian measures. In this way Professor Flinders Petrie obtained 20·62 inches or 0·525 metre for the cubit used in the construction of the Great Pyramid; a doorway of Khnumhotep's tomb at Beni Hasan (No. 3) is stated to be 7 cubits high, while its measured height is 142·7 inches,* corresponding to a cubit of 20·4 inches or 0·520 metre. Edfu Temple, the grave of Rameses IV, and other buildings give more or less accordant results. We might expect to get even more reliable results from the scales of the nilometers which were erected in all the principal towns and of which several still exist, but a careful examination of these has shown that they were often inaccurate and that no great care was exercised in engraving them on the masonry walls of the stairways in which they were placed;† a summary of their lengths is given in the following table :—

Nilometer.	No. of cubit lengths	Length in metres of		
		longest cubit.	shortest cubit.	average cubit.
Philæ I	12	0·538	0·510	0·520
Philæ II	12	0·539	0·519	0·532
Philæ III	16	0·545	0·525	0·535
Elephantine	12	0·545	0·517	0·523
Edfu	6	0·550	0·519	0·528
Esna	9	0·542	0·500	0·532
Luxor	6	0·540	0·520	0·529

Thus the value furnished by them is of no high accuracy, but agrees reasonably with that derived from the rods and the buildings, viz., 0·525 metre for the length of the large or royal cubit.

* According to Mr. G. W. Fraser's observation.

† Cf. Borchardt, "Nilmesser und Nilstandmarken." Abhandlungen d. königl. preuss. Akademie d. Wissenschaften. Berlin, 1906.

For measuring land the unit employed was 100 royal cubits or 52·5 metres ; it was termed the *khet*, or *khet-n-nuh*, " the reel of cord," since a twisted cord of this length divided into sections by knots, and terminated by end-pieces, was used to determine the dimensions of properties.* Such a cord is shown in representations of land-measurers at work on the walls of tombs, and it is also portrayed in the statues of officials entrusted with the supervision of lands (see Plates I, II, and III). There was also a longer measure, the *ater*, corresponding to the *schœnus* of the Greek authors, which was used for itineraries, or for describing long distances, and not usually for surveying purposes. It is employed in the inscriptions on the boundary-stones of Ikhnaton at Tel el Amarna to define the lengths of the sides which enclosed the lands allotted to the new city.

Areas were reckoned in squares of the *khet*, or 100 royal cubits, each such square being called in Egyptian *set* and in later times by the Greeks *aroura*. It was considered as being composed of 100 " cubits of land," each of which was 100 cubits long by 1 cubit broad. This form of the unit of area was doubtless due to the long and narrow rectangular plots being the most convenient form in which to divide the land both for ploughing it when holdings were small and to retain access to the water-channel which conveyed the flood water to it ; the predominance of this shape of holding at the present day may be seen in any sheet of the cadastral map of the country (see Plates VIII, and XXVI) except where local conditions favour more irregularly shaped plots, as in the Fayum, where the slope of the ground is considerable, and in the northern Delta, where land is poorer, and the holdings are large and bounded by winding water-channels.

The divisions of the *set* or *aroura* in Egyptian times were the half, the quarter, and the eighth, after which the cubit became the unit, but in late Ptolemaic times the subdivisions were continued to the thirty-second part, and the Greeks carried them further to the sixty-fourth.

A half *aroura* was also in use in late Egyptian times, and this exemplifies the approximate methods used, for it was called *remen* or the upper arm. The *remen* was a measure of five palms, whereas the royal cubit contained seven palms, so that their squares contained

* Measuring rods were also used as well as cords.

twenty-five and forty-nine square palms respectively, or a proportion of nearly one to two. At Aniba, a village nearly opposite Ibrim in Nubia, there are some tombs in which the extent of certain estates is represented by notched rectangles, each of which corresponded, doubtless, to a *set* or *aroura*. Small areas, such as a well or tank, were stated in square cubits.

There was also a larger unit of area, "the 1,000 of land," which consisted of ten *arouræ*, each of which included 100 "cubits of land." This unit was the one which was mostly employed in describing property of any size, and, being equal to 6·5 feddans, was in fertile districts a valuable piece of land.

Thus the units in use in ancient times for land-measurement were:—

LENGTH.

Royal cubit	=	0·525	metres
Khet = 100 cubits	=	52·5	„
Ater = about 4,000 cubits	=	2,000	„ approx.

AREA.

1 square cubit	=	0·27	square metres	
1 cubit of land = 100 square cubits	=	27·287	„ „	or 3·75 sahms *
1 set or aroura = 100 cubits of land	=	2,728·7	„ „	or 0·65 feddan
1 "thousand of land" or 10 arouræ	=	27,287	„ „	or 6·5 feddans

The importance of preserving the correct values of their measures of length and area was fully recognized by the ancient Egyptians, and we find evidence of this in their religious literature† where the deceased is represented as saying, when he enters the Hall of Truth before the god Osiris:—

> "I have not diminished the cubit measure."
> "I have not falsified the field measure."

These units of length and area do not seem to have altered much during the period of Egyptian history so far as the somewhat meagre information which remains enables us to judge. The collections of Greek and Roman papyri which have been recently found at El Hiba, Bahnessa, in the Fayum, and at other sites in Egypt have thrown

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* See page 40, and Appendix III.

† "Book of the Dead" ch. 125, quoted by ERMAN in "Egyptian Religion," Eng. trans., p. 10

much light on the conditions of life in Egypt between the last of the Egyptian kings and the Arab conquest. Among much other valuable information which has been preserved and which has been unexpectedly recovered of late years, is a list of the measures of length which are given in a papyrus (No. 669) which was found at Oxyrhynchus (Bahnessa) in 1903 by Professor B. Grenfell and Dr. A. Hunt, dating from about 290 A.D. * ; the measures are as follows :—

				metres
2	palms	make a	λιχάς	0·150
3	„	„	„ σπιθαμή	0·225
4	„	„	„ ποῦς	0·300
5	„	„	„ cloth-weaver's cubit	0·375
6	„	„	„ public and a carpenter's cubit	0·450
7	„	„	„ Nilometer or Royal cubit	0·525
10	„	„	„ βῆμα or the distance of the outstretched feet	0·750
3	cubits	„	„ public ξύλον	1·575
4	„	„	„ ὀγυιά	2·000
?	„	„	„ κάλαμος	?
$6\frac{2}{3}$	„	„	„ ἄκαινα...	3·28
40	„	„	„ ἄμμα	21·0
96	„	„	„ schœnium of land-surveying	50·38
100	„	„	„ schœnium...	52·50

The *schœnium*, like the *khet* in earlier times, was the side of the square *aroura* or *set*, and measured 100 royal cubits of 0·525 metre ; thus the *aroura* contained about 2,729 square metres, or 0·65 feddan as already mentioned; but the papyrus just quoted says that the *schœnium* used in land surveying was a square of 96 cubits side—one probable reason for the change being the greater convenience in estimating the thirty-second and other factions of the *aroura ;* given that the cubit was the same, this *aroura* would be equal to 2,645 square metres, or 0·634 feddan.

These measures continued in use down to the time of the Arab conquest of the country or very nearly to that date, for papyri dating from the sixth and seventh centuries contain references to land of which the area is stated in *arouræ.* Papyrus No. 131 of those found at Oxyrhynchus by Professor Grenfell and Dr. Hunt speaks of half an *aroura* of land, and is dated by them as belonging to the sixth

* The Oxyrhynchus Papyri, Part IV. Egypt Exploration Fund. London, 1906.

or seventh century.* In an Arabic papyrus from the Fayum (No. 597 in the Vienna Collection of Arabic Papyri†) dated 106 A.H. (724 A.D.), a new measure of area, the *feddan*, is mentioned and henceforth completely replaces the older measures. It is a Syrian word, *faddâna* = *jugum*, acre, and was derived originally from Babylon—*padana* = plain.

It is not a little remarkable that so radical a change in the land measures of an agricultural country should have been so quickly accomplished, seeing how considerable an alteration was involved. For the *aroura* of 96 *shœnia*, or 2,645 square metres, was introduced the feddan of 400 square *qassabas ;* the divisions of the feddan were the $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{12}$, $\frac{1}{24}$. Instead of being founded on an arbitrary unit of length such as the cubit, the feddan was primarily the area which could be ploughed in a day under favourable conditions. Though so complete a change took place in the measures of length and area, those of capacity remained unaltered, for the "ardeb" still exists as the descendant of the ἄρταβα of Ptolemaic times.

In a nilometer scale of late date which was found on a marble column at Kom el Giza in Beheira ‡ two scales are engraved; in one the mean length of the cubit is 0·575 metre, the longest and shortest cubits measuring respectively 0·580 and 0·570 metre; in the other the corresponding lengths are 0·667, 0·670 and 0·663 metre.

The feddan originally consisted of 400 square qassabas, but the length of the qassaba varied considerably; it is defined as being equal to 6 Hashimite cubits or 6 $\frac{2}{3}$ cubits known as dira'a el kerbas, or 7 cubits and 2 palms of a smaller cubit. § Mahmud Pasha el Falaki §§ states that the length of the qassaba in Roman times was 3·94 metres, but he does not state his authority and is probably identifying it with some measure then in use, but with insufficient proof. He is on firmer ground when he gives the Hashimite qassaba as equal to 6 $\frac{2}{3}$ dira'a beladi or 3·884 metres. De Sacy, in the notes to his translation of

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* "Oxyrhynchus Papyri," I. Egypt Exploration Fund. London 1898.

† Communicated by Dr. B. Moritz.

‡ Daressy, "Annales du Service des Antiquités," Cairo 1906.

§ Cf. Sauvaire, "Journal Asiatique," Paris. 1883-7, vols 7, 8, 10.

§§ "Le Système métrique en Egypte," Copenhagen, 1872.

Abdellatif's history,* quotes from the Annuaire de la République Française (Cairo, year IX, 1801) a statement that the ordinary qassaba then in use in Upper Egypt was equal to 6 $\frac{2}{3}$ dira'a beladi, or 3·85 metres, but that the one used by the Coptic land-measurers was only 6 $\frac{1}{3}$ dira'a; their feddan, therefore, contained about 5,250 square metres against 5,720 in that of the ordinary feddan, or in the ratio of 0·92 to 1·00. Jomard states that a legal qassaba of 6 $\frac{2}{3}$ dira'a beladi, which were each equal to 0·5775 metre (so that the qassaba contained 3·85 metres) was found in a mosque at Giza during Napoleon's expedition and the length was then verified. When Mohammed Ali ordered the cadastral measurement of the cultivable lands in 1813 the length of the qassaba varied in different provinces but later on it is stated by Mengin † to have been 3·64 metres, and Lane also notes that he was told by the Italian engineer Masi, who was employed on this survey about 1823, that the qassaba equalled 3·64 metres.

At this time there were undoubtedly many lengths of the qassaba since it varied in different parts of the country, and with the choice of the measurer; that of 3·64 metres used by Masi ‡ was very probably the mean length of those which he found in use by the inhabitants of the villages which he surveyed in Sharqia. It was not until 1861 that a decree dated 15th Zil Qaada, 1277 A.H., was signed by Said Pasha, defining the qassaba as a length equal to 3·55 metres, and then for the first time the feddan became a definite unit of area equal to 333 $\frac{1}{3}$ square qassabas, each containing 12·6025 square metres. We find that several lengths were in use between 1813 and 1861 besides that of 3·64 metres used by Masi; Wilkinson found it in 1825 to be from 11 feet 7$\frac{1}{4}$ inches to 11 feet 4$\frac{1}{2}$ inches, or from 3·54 to 3·48 metres. This is considerably less than that of Masi, but agrees well with that still used in the villages of Upper Egypt. In Bahgat Pasha's Cadastre of 1270–1276 A.H. (1853–1859 A.D.) the qassaba used seems to have been of about this length (see chapter VI). The length of the qassaba then used can, however, still be determined with a fair accuracy from the dimensions recorded in the registers of the Cadastre of 1270–1276

* "Relation de l'Egypte" translated by S. DE SACY. Paris, 1810.

† "Histoire de l'Egypte sous Mehemet Ali," Paris, 1823.

‡ Further information is doubtless obtainable from MASI'S book which, however, I have been unable to obtain.

A.H. of distances which can be recognized to-day upon the ground. In this way values of 3·50 metres and 3·46 metres were obtained in two villages of Sohag District * and others in Wasta District varied between 3·48 metres and 3·60 metres.† These old land-registers are still in use for the reasons which are given on p. 70, and the method of obtaining the original unit of length which was employed is to carefully measure a distance with the legal qassaba of 3.55 metres, to compare the length so determined with the number of qassabas recorded in the register, and then to make a new qassaba rod of a length which will correspond to that with which the old measurements were made. In this way any excess or deficit which might be caused by laying out the measurements of the old cadastre with the new legal qassaba is avoided. In the provinces of Assiut and Qena, qassaba rods were met with‡ during the recent cadastral survey which were of various lengths from 3·40 metres to 3·50 metres.

There have been, moreover, many sizes of feddan in use which varied in different parts of the country and for different qualities of land, since in undeveloped communities where taxes are paid in kind it is often found more convenient to fix upon a certain quantity of produce to be furnished from a certain area, and to vary the size of the unit according to the quality of the land, than to employ the converse method where a varying amount is due from a definite area proportionately to the quality of the land, as is done when fiscal procedure becomes more highly organized. The unification of the feddan throughout the country has, therefore, been one of the results of the recent cadastral survey.

Besides the normal feddan of 400 square qassabas of 3·85 metres, several other feddans were in use in Lower Egypt at the beginning of the nineteenth century, when the French savants prepared their exhaustive description of Egypt. One, for land near the Nile, contained 4,580 square metres or about 310 square qassabas, while on other land situated far from the main branches of the river it contained as much as 8,140 square metres or about 551 square qassabas; at Damietta there was a feddan in use of 6,905 square metres or 470

* By Mr. H. G. Skill.
† By Mr. V. L. O. Sheppard.
‡ By Mr. G. H. Morgan.

qassabas. No doubt other variations could be found by an examination of old title-deeds for feddans of different size existed up to the present time in both Menufia and Qaliubia provinces. Some deeds from Qaliubia refer to a small feddan of 200 square qassabas and a large feddan of 400 square qassabas.* The size of the feddan was laid down as being equal to 333 ⅓ square qassabas by Mohammed Ali Pasha in 1813 which, taken together with the definition of the qassaba as a length of 3·55 metres in 1861, fixed the area of the feddan as equivalent to 4,200·833 square metres, which definition was maintained in the Khedivial Decree of April 28, 1891. Land is still sometimes leased in Sharqia province by the feddan of 300 square qassabas to compensate the landlord for roads, canals, etc., on which he pays tax but which are excluded from the tenant's feddan. The smaller feddans which were still in use continued to be described as being of 18, 20 or 22 qirats, or twenty-fourths, of the legal feddan and during the survey of Qaliubia in 1903, documents were seen which related to feddans of 21½ and 23 qirats, while in the waste lands north of Belqas others of 25, 26 and even 30 qirats were found.† During the recent survey all land was measured under the Decree of April 28, 1891, in feddans of 4,200·833 square metres.

The present units of length and area for land-measurement, according to this decree, are :— ‡

Primary	1	Dira'a beladi...	=	0·58	metre
	1	Qassaba of 24 Habbas... ...	=	3·55	metres
Derived	1	Square Qassaba	=	12·6025	square metres
Primary	333⅓	Square Qassabas = 1 feddan of 24 Qirats	=	4200·833	square metres
Derived	1	Sahm	=	7·293	square metres
	24	Sahms = 1 Qirat	=	175·035	square metres

Closely related to the measures of length and area are the methods of computation employed to obtain from the linear measurements the area of the different holdings, and some account of them will not be out of place, since they illustrate remarkably the extraordinary vitality of old customs. In the Rhind Papyrus, which is now in the British Museum, we have a number of examples of mathematical problems

* Communicated by Girgis Bey Henein of the Ministry of Finance.
† Mr. G. H. Morgan.
‡ See Appendix I.

together with the methods employed for their solution. They cover a wide range of mensuration but that portion with which we are concerned is contained in sections 49–53, which relate to the measurement of land. The papyrus dates from before 2000 B.C., so we may consider it as typical of the methods universally employed in ancient Egypt. We shall see that they have been retained in use not only in Roman times, but throughout Egypt until the present day.

In this papyrus, rules and examples are given for the computation of the area of a rectangular field, of a circular field, of a triangular field, of a four-sided trapezoidal field, and for cutting off a piece of land of given size from a larger piece. From these we see that the Egyptians not only obtained the area of a rectangle by multiplying a long side by a short side, but extended the same rule to any four-sided figure, where one long side or the mean of the two long sides was multiplied by the mean of the shorter sides. The isosceles triangle was dealt with similarly, one side being multiplied by half of the base. Their fundamental error was that they treated the right-angle only and ignored all others. It would seem as though this was their primitive method, which was at first found sufficiently accurate for practical requirements ; later on, as more precision was needed, it was obtained, as the village land-measurer now does, by suitably laying out the pieces for measurement so as to obtain satisfactory figures, rather than by improving the method of computation, though it cannot be said that this was beyond their powers. They had long dealt with angles of less than 90° in laying out slopes of buildings, etc., and the step from that to dealing with such angles on the ground was not a long one. Borchardt has shown that slopes such as those of the faces of the pyramids and mastabas were defined by the relation of the base of a triangle to its perpendicular, which was a cubit long ; if the base was 6 palms to 7 of the vertical cubit, the angle would be 49° 24′, if 5 palms 54° 28′, if 4 palms 60° 15′ and so on. It was not until the first century B.C. that Hero Alexandrinus* gave the correct formula for the area of a triangle, but even then it was not adopted in the country, for we find at Edfu temple in late Ptolemaic times the old method for determining a triangular area employed. This method of obtaining

* Cf. "Herons von Alexandrien Vermessungslehre und Dioptra," by H. Schöne. Leipzig, 1903.

the area of any triangle was to assume it to be isosceles and to employ the formula:

$$A' = \frac{ab}{2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (1)$$

where a = the base and b is one of the equal sides, instead of the correct formula:

$$A = \frac{ab}{2}\sqrt{1 - \left(\frac{a^2}{2b}\right)} \quad \ldots \ldots \ldots \ldots \ldots \quad (2)$$

Under certain circumstances these methods may give rise to considerable errors. The limiting values of b in formula (2) for any given value of a are a and ∞. If b is greater than a the error due to the employment of formula (1) diminishes rapidly as the ratio of b to a increases; for instance when $b = 2a$ the error amounts to only 3 per cent. of the area.

The errors in the area of some isosceles triangles are shown in the following table in terms of the incorrect area given by formula (1): *

Base	Side	Area A' by formula (1)	Correction to area A' in terms of A
a = 1	b = 0·7071	0·354	— 0·293
a = 1	b = 0·8	0·400	— 0·219
a = 1	b = 1	0·500	— 0·134
a = 1	b = 2	1·000	— 0·031
a = 1	b = 3	1·500	— 0·014
a = 1	b = 4	2·000	— 0·008
a = 1	b = 5	2·500	— 0·005

Just as the rule for rectangles was incorrectly extended to all four-sided figures, thereby introducing errors which might rise to any proportion of the whole, according to the obliquity of the figure, so also did the Egyptians extend their inexact rule for isosceles triangles to all triangles, since their areas were obtained by taking half the product of the base multiplied by the mean of the two sides.

For four-sided figures they employed the formula :

$$A' = \frac{a + b}{2} c \quad \ldots \ldots \ldots \ldots \ldots \quad (3)$$

instead of:

$$A = \frac{a + b}{2} c \sqrt{1 - \left(\frac{ba}{2c}\right)^2} \quad \ldots \ldots \ldots \ldots \quad (4)$$

* See Professor HAMMER in "Zeitschrift für Vermessungswesen." Stuttgart, 1908, pp. 377-384.

Thus the results obtained were always in excess of the correct amount except when the plot of land was a rectangle.

The inconveniences of this system were largely reduced by the great majority of the plots being rectangular, as they still are to-day (see Plans VIII, X, etc.), but nevertheless a proportion of triangular, trapezoidal, or irregularly shaped plots must always occur, and then the accuracy of the results depends on the skill of the measurer in so taking his measurements as to minimize the effect of an incorrect method of computation.

In Greek and Roman times computations of area followed the same rules, as is to be seen from the papyri that have been found in recent years.* In them the lengths of the sides are stated and the area deduced ; this does not in most cases differ much from what the maximum area would be when the plot was rectangular, so that the majority of the plots, then as now, did not probably vary greatly from this shape. In Papyrus No. 61 b from Tebtunis the difference found between the supposed area of a piece of land and that found by measurement at the time is referred to and it is to be noticed that the latter is always the greater. The reason of this is not stated and we are left to imagine it. Several solutions are possible. The original measurements may have been based on the schœnium of 100 cubits, and the subsequent land-measurers may have used theirs of 96 cubits. Again, if an area was first measured as a whole and then re-measured after subdivision into a number of plots the total of the latter would probably exceed the first total since the errors due to the methods of computation were always such as to increase the result. Beyond the superior skill of a more experienced measurer there do not seem to have been any methods of superior accuracy which were used as a control upon the ordinary measurements. The errors hitherto discussed are those due to the inherent inaccuracy of the formulæ employed. Other sources were the consistent neglect of fractions of the aroura less than $\frac{1}{64}$ (43 square metres), a much larger amount than the sahm (4·7 square metres) which the local measurers to-day claim to work to.

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* See GRENFELL and HUNT, "Tebtunis Papyri." London, 1902, p. 386 ; and KENYON, "Catalogue of Greek Papyri in the British Museum." London, vol. II, p. 129.

Gross errors were certainly not infrequent, and complaints of them, as well as petitions for re-measurement, often occur. A typical instance is given in Papyrus No. 660 in the Erzherzog Rainer-Führer * ; the first measurement of a property gave 200 feddans as its area, but the daughter of the owner, one El Hassan, complained, saying that there were only 130½ feddans ; a re-measurement gave 148 feddans as the result, the different amounts thus being in the proportion of 1·00, 1·13 and 1·53.

No change was made in the methods of computing during the period of Arab domination ; the old methods continued in use and are in use to-day in the villages of Egypt and most of the local offices. When the survey of State lands was commenced in 1892 the larger properties and the divisions of the villages were computed by modern methods, but all small plots were calculated according to the ancient rules.† As the reorganization of the country progressed during the last quarter of a century the value of the land increased and owners began to object to inaccurate methods. Saber Bey Sabri ‡ made suggestions for improving the measurement by the qassaba rod. He pointed out not only the erroneous character of the computation but also the inaccuracies caused by incorrect alignment, by points being roughly marked by undressed lumps of stone, and by sloping ground not being treated specially. He stated that a skilful measurer using the qassaba rod could obtain results for the length of a line which would vary by as much as 5 per cent.

In the year 70 A.H. (690 A.D.) the Khalif Abdul Melek Ibn Merwan ordered that the accounts, which had hitherto been kept in Coptic, should in future be kept in Arabic. The Copts, who were the accountants of the country, wrote the numbers in those Arabic letters which were used for numeration but for the fractions they continued to use the older Coptic signs. In the twelfth century, when Arabic numerals were introduced, they were adopted in place of the letters, without, however, displacing the signs for the fractions. When Mohammed Ali reformed the accounts of the country in about 1820 the Coptic signs for the fractions of the piastre soon disappeared, but the change did

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* C. Becker, "Beiträge zur Geschichte Aegyptens." Strassburg, 1903. p. 119.

† See Chapter IX.

‡ "Bulletin de l'Institut Egyptien." Cairo, 1890. pp. 96 *et seq.*

not affect the cadastral units, and until recently, while the feddans were written in figures, the fractions of the same were in the old Coptic signs, which are found in many lists of land to-day

In 1878, a reorganization of the accounts was effected under the direction of Sir G. Fitzgerald, and from this time the feddan was recorded as containing twenty-four qirats of twenty-four sahms; this practice soon spread to the provinces and may now be said to be universal throughout the country. In 1886, the Ministry of Finance by Circular No. 117, dated September 25, ordered that fractions of feddans were to be indicated in qirats and sahms and not by the signs for the fractions of a feddan which had previously been used. These fractions were $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{6}, \frac{1}{8}$.*

* Yacoub Pasha Artin, "Signes employés dans la comptabilité copte en Egypte pour la transcription des fractions." Bull. Inst. Egypt. 1889. p. 285.

See also "Journal Royal Asiatic Society," Aug. 1879.

CHAPTER IV.

Land Survey before the 19th Century.

Previous to the nineteenth century of our era we have but meagre information concerning land-measurement, the classification of land, and other branches of the surveyor's work. From time to time an inscription or a papyrus throws directly or indirectly some light upon the subject, but the total amount which we now possess is still very inconsiderable.

The recorded heights of the Nile flood in each year of the first dynasty show that the Egyptians had as early as that time made considerable progress in the science of measurement and recognized its importance.* Besides the records of the annual flood, the Palermo Stone mentions the stretching of the (measuring-)cord at the foundation of a temple, that is, the plan was pegged out on the ground. In these early times Professor Breasted † is of opinion that the land all belonged to a noble class, so that a considerable part of the country consisted of large estates administered by these nobles, as was also the case in the period which immediately followed. Every two years a "numbering" of the royal possessions was made throughout the land by the officials of the treasury, and this would be a sort of verificatory survey of State property which doubtless included herds as well as lands. This biennial census was so regular a procedure of the administration in these early times that events in the reign of the king were dated with reference to it.

Soon after this early period we meet with the first traces of the registration of property, for about 3000 B.C. the property of a high official, Methen,‡ was recorded in the third dynasty on the walls of his tomb at Saqqara; it is stated to have been duly registered as belonging to him in the royal archives or registry. There must, therefore, have been at this time a well-developed method of measuring the

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* Schäfer, "Abhandlungen d. königl. preuss. Akademie," 1902.

Naville, "Recueil de travaux relatifs à la Philologie et à l'Archéologie égyptiennes et assyriennes," 1903, p. 64.

† "A History of Egypt." London, 1906, p. 64.

‡ Breasted, "Ancient Records," Chicago, pp. 171-5.

land and of computing the area of properties. It was not long before the registration of land and its measurement became highly organized, as would be essential in a country where all payments of taxes were made in kind and rent was paid in the same way.

Another of the tombs at Saqqara, that of a certain Mes,* furnishes us with information of exceptional interest. Certain lands near Memphis which the Pharaoh Amosis (1580 B.C.) had conferred on an ancestor of Mes named Neshi were, during the minority of Mes, claimed by a certain Khay as his property. A lawsuit followed in which Khay produced false title-deeds, whereupon Nubnofret, the mother of Mes, appealed to the official registers, saying, " Let there be brought to me the registers from the Treasury and likewise from the Department of the Granary of Pharaoh."

A commission was sent by the court to make extracts from the registers, but by means of falsified copies Khay gained his case, but was, however, non-suited on appeal when the evidence of many neighbouring landowners was taken.

In later times, about 900 or 850 B.C., the register of the lands and springs in the Oasis of Dakhla is referred to in an inscription which tells of a lawsuit concerning the ownership of a spring; nineteen years elapsed before a decision was obtained. †

Thus, the owner's name, the area of the property, its position, and the tax due from it were regularly recorded, and, in the New Empire at least, duplicate registers were kept in the Treasury and the Royal Granary.

No attempt was made to measure angles of different sizes, but all were treated as though they were right angles; where the details of boundaries are given in ancient Egyptian inscriptions, as well as in the title-deeds of the Græco-Roman period, the boundaries are always given as the north, the south, the east and the west, and the same practice continues to-day in all village title-deeds. This method, which is derived from the time when land-surveying was in its most elementary state, prevents any map being made which can lay claim

* LORET, "Aegyptische Zeitschrift," 39 (1901). MORET, *ibid.*

GARDINER, "The inscription of Mes," "Untersuchungen zur Geschichte und Alterthumskunde Aegyptens," IV, 3, 1905.

† SPIEGELBERG, "Recueil de travaux, etc." 1899, p. 12.

Ancient land-measurers at work. (Thebes).

to be more than the roughest diagram, since the assumption on which it depends, viz., that all plots are rectangular and all their sides are correctly oriented to the cardinal points of the horizon, is only fulfilled in rare instances. The vain attempt to reconcile such descriptions of landed property with the ground itself is a never-ending source of trouble and delay in surveying to-day, and in some places an additional complication is introduced, since north and south in the Nile Valley are usually synonymous with downstream and upstream; but where the river flows south instead of north, as it does just below Qena, north is still retained as equivalent to downstream (see p. 24, and Plan IX).

The natural river-arms and backwaters were utilized and modified to form canals, and very seldom, if ever, was a straight canal dug for a long distance in ancient times. The plots were arranged at right angles to the water-channels for convenience of supply, and consequently they lay in every possible azimuth as they followed the windings of the stream, so that boundaries described as corresponding to the four cardinal directions were of very little assistance in locating a piece of land.

The inscription in the tomb of the Vizier Rekhmara * at Thebes refers to his duties in the land-court where he heard and decided cases of disputed ownership in land; all titles that had been approved as being in order were registered, but unregistered claims were ignored.

Incidentally, land of different classes and of varying qualities is mentioned from time to time in the inscriptions, but no complete list of them is known. A monarch of Assiut about 2300 B.C., one Khete, whose tomb inscriptions bear witness to a well-established state of land-tenure and administration, speaks of a canal which he made in order to irrigate high land which otherwise could not be cultivated,† and a certain Sebek-nekt records in his tomb at El Kab that his property consisted of twenty "thousands" of the low-lying valuable land and a hundred and twenty "thousands" of the poorer high ground.

The marking-out of the province boundaries was considered from early times of great importance and inscribed stelæ were placed on the

* NEWBERRY, "The Life of Rekhmara," London, 1900.
† BREASTED, "Ancient Records," Chicago, 1906, I. p. 407.

limestone cliffs on either side of the valley in order to define them in a permanent manner, which have in some cases been preserved until the present time. They were not confined to the desert margins alone, but the inscription of Khnumhotep II in his tomb at Beni Suef records that the king Sesostris II "made monuments in the Jackal nome restoring that which a city (village) had taken from its neighbour, causing him to know his boundary according to the record, investigating according to that which was of old, putting a landmark at his southern boundary perpetuating the northern like the heavens, establishing on the fields of the low ground a total amounting to fifteen landmarks: establishing upon its northern fields as far as Oxyrhynchus (Bahnessa). He divided the great river along its middle, its western side going to the Jackal nome (district) as far as the western high land. . . ." *

In the eighteenth dynasty King Ikhnaton set up stelæ on both sides of the Nile Valley in order to delimit the district. Fourteen of these are known to-day, eleven being on the east side of the river and three on the west. In the inscription the length of the district "from the south tablet as far as the north tablet measured between tablet and tablet on the east mountain of Akhetaten (the town) amounting to 6 ater $\frac{1}{2}$ and $\frac{1}{4}$ of a khet and 4 cubits, likewise from the south-west tablet of Akhenaton to the north-west tablet on the west mountain of Akhenaton amounting to 6 ater $\frac{1}{2}$ and $\frac{1}{4}$ of a khet and 4 cubits likewise exactly, and the area within these four tablets, from the east mountain to the west mountain, is Akhenaton in its proper self, it belongs to Father Hor Aton in mountain deserts, islands, upper ground, lower ground, land, water, villages, embankments, men, beasts, groves, and all things which the Aton my father shall bring into existence eternally for ever." †

No map of landed property in ancient Egypt has come down to us, but on the tomb walls we meet with representations of land-measurers at work. Their methods of land-measurement are represented on the walls of the tomb of one Menna ‡ at Thebes, a land overseer and inspector of the boundary stones of Amon. The tomb, which is situated in that portion of the Theban burial-ground known as Sheikh

* Breasted, "Ancient Records," Chicago, 1906, I. pp. 624, 626, 632.

† N. de G. Davies, "The Rock Tombs of El Amarna," Pt. V. "Archæol. Survey of Egypt," London, 1908.

‡ Borchardt, "Zeitschrift für Aegyptische Sprache," 1905, p. 70.

Ancient land-measurers at work. (Thebes).

Abd el Qurna, has recently been cleared out by Mr. R. Mond (see Plate I). The scene depicted shows two chainmen measuring a field of corn with a long cord on which are knots or marks at intervals which seem to be about four or five cubits in length: each also carries a spare cord coiled up on his arm. Beside them walk three officials, who carry writing materials and who are accompanied by a small boy carrying writing materials and a bag in which are probably documents and plans referring to the property. An old man and two boys also accompany the surveyors, and a peasant brings a loaf of bread and a bunch of green corn.

A similar scene is pictured on the walls of a tomb belonging to a certain Amenhotep, also at Sheikh Abd el Qurna (see Plate II). Here only one man accompanies the chainmen, each of whom, as usual, carries a spare cord. The figures are larger than in the tomb of Menna, and though they are much damaged, it is possible to see that the cord terminated in a ram's head. This is also shown in the statue of the priest Pa-en-hor from Abydos, which is now in the Cairo Museum (Cat. No. 4,875); he is represented in a kneeling position and is holding a rolled-up measuring-cord, at each end of which is a ram's head (see Plate III).

Besides measurements of land, the pyramids, temples, and rock-tombs furnish numerous examples of accurate measuring; and among them the Pyramids of Giza provide perhaps the best known and most fully studied instances.

Not only were the Egyptians of these remote times competent to measure lands and lay out large buildings, but they had attained a very satisfactory accuracy in levelling, and of this the Pyramids of Giza again furnish proof.* Borchardt, in his paper on "Nilmesser und Nilstandsmarken," † adduces many facts in support of the view that they carried out a line of levelling from the head of the Delta to the First Cataract in connection with the nilometers which were built at every important town; and this, too, was done with a very fair accuracy, since the average slope deduced from the scales on these nilometers works out at 1 in 14,440 against 1 in 13,700, as given to-day by the levels of the Irrigation Service. The instrument used was a

* Flinders Petrie, "The Pyramids of Giza." London, 1883.
† "Abhandlungen d. königl. preuss. Akademie," Berlin, 1906.

right-angled isosceles triangle of wood, with a plumb-line attached to the apex; it was doubtless used on a long wooden straight-edge, which in its turn rested on pickets. In this way, levelling of a very fair accuracy could be rapidly executed.

The rich harvest of papyri dating from Ptolemaic and Roman times which have been recovered in recent years furnishes much valuable and interesting information concerning the measurement of land, its registration, its quality, and many other matters of a similar character.

A particularly complete collection of official papers from the bureau of Menchis, the *komogrammateus*, or government scribe, of Kerkeosiris, close to Tebtunis, was found in 1899–1900 by Professor Grenfell and Dr. Hunt when they were excavating the site known as Um el Baragat, the ancient Tebtunis, on the south side of Gharaq in the Fayum, and was published by them in 1902. The papyri date from about 120–111 B.C., and deal largely with land-measurement, land-registration, and kindred subjects.

This village of Kerkeosiris contained 4,700 *arourœ*, or about 3,100 feddans of land which in the fifty-second year of Ptolemy Euergetes II (119–118 B.C.) were distributed in seven different categories (see p. 58).

Another papyrus from Tebtunis gives a detailed description of certain small plots of land on the east side of Crocodilopolis Arsinoe (Medinet el Fayum) between the road round the town and a large canal.

The dimensions are given in *schœnia*, and the plots are of the usual small size; some belong to private individuals, one belongs to the queen, another is recorded as common land, while a public road between the private property and a public canal is separately registered. The same conditions may be exactly paralleled round Medinet el Fayum to-day.

Without doubt the land-measurers of this period were but continuing the procedure of earlier times in the methods which they employed. Lines were measured along the heads of the plots, the breadth of each field being recorded as well as its length; from this the areas of rectangular fields could be calculated. Frequently the lengths of all the sides were recorded and the area was then computed by obtaining the product of the means of the opposite sides whatever the angles of the figure might be. The part of the village lands in which the line starts is described and then the detail measurements are recorded. On

Statue of the priest Pa-en-hor (Abydos).

completing the line, the surveyor usually took another at right angles, or approximately so, to the first direction and recorded the dimensions of the plots which abutted on the line. The name of the owner of each plot was inscribed at the same time. In this way the whole of the lands of the village were measured up and their owners recorded. The system employed in the cadastral measurements of 1813 and 1853-1859 was essentially the same, since it was the one which was most suitable to the circumstances of the case. Modern improvements consist in controlling the lengths and areas by fixed points at known intervals, and by areas carefully computed, while the holdings are plotted on a map to avoid omissions or repetitions; angles are measured, and are not assumed to be right angles, and the methods of computation are correct. The following translation * of a portion of papyrus No. 86 from Kerkeosiris 1, 8-31 which refers to land at Crocodilopolis Arsinœ gives an example of the method used:

(8) Adjoining on the north (the land of) Demetrius son of Thrax formerly in the possession of Micion,

(9) namely 4 $\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{8}$ of unirrigated crown land, of which 4 $\frac{1}{2}$ are occupied by the discharge of the bath of Hippon

(10) and $\frac{1}{4}$ $\frac{1}{8}$ of crown land by the conduit of the said Hippon.

(11) The neighbouring areas are: on the south the conduit of Apollonius, on the north the unirrigated land of Hermione

(12) on the west the precinct of the city, on the east the canal of Argaitis.

(13)

(14) Adjoining on the north the land of Hermione, daughter of Apollonides, namely 5 $\frac{1}{4}$ $\frac{1}{8}$ $\frac{1}{16}$ $\frac{1}{32}$ arouræ, of

(15) which $\frac{1}{4}$ is occupied by a reservoir, $\frac{1}{32}$ by an abandoned pigeon-house, $\frac{1}{16}$ by a tomb (?),

(16) and 5 $\frac{1}{8}$ is unirrigated. The neighbouring areas are: on the south the unirrigated land of Demetrius son of Thrax, on the north

(17) land of a synagogue, on the west the precinct of the city, on the east the canal of Argaitis.

(18) Adjoining on the north the land of a synagogue of the Jews, through Pentollas

* Kindly furnished by Dr. A. Hunt.

(19) and leased by Petesuchus son of Marres,

(20-21) namely 3 $\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{16}$ arouræ of temple garden land, and 1 $\frac{1}{2}$ of land growing garland-flowers and vegetables.

(22) The neighbouring areas are: on the south the land of Hermione daughter of Apollonides, on the north and west

(23) the precinct of the city, on the east the canal of Argaitis.

(24) Adjoining on the north, receding on the west side next the city 4 $\frac{1}{2}$ schœnia

(25) the land of Sarapion, agent of the queen, namely 1 aroura of temple land, of which

(26) $\frac{1}{2}$ is occupied by abandoned houses, and $\frac{1}{2}$ is uncultivated.

(27) 18

(29) The neighbouring areas are: on the south the land of the synagogue of the Jews, on the north and west the precinct of the city,

(30) on the east the canal of Argaitis.

(31) This brings us to the precinct of the city on the north.

Thus the well-established methods of land-measurement, which had been developed in the course of centuries, continued in use without modification for a long period, and as we have seen, in Greek and Roman times there are no important changes to chronicle.

The measurement of an arc of meridian between Alexandria and Aswan by Eratosthenes in about 230 B.C. was an event of great geographical importance, since he derived from it a value for the circumference of the earth. His achievement is, however, more closely connected with geodesy and topographical surveying than with cadastral measuring for at that time neither the instruments used nor the methods employed were of sufficient precision to afford any means of controlling the field-measurements.

After the conquest of Egypt by the Arabs, Coptic land-measurers were still employed, but gradually Arabic writing and numerals were introduced as related in the last chapter.

From time to time a cadastre or re-measurement of lands is said to have been carried out, but this only meant that the area and sometimes the dimensions of each property were measured in each village but no attempt was made to record them graphically so as to form a map.

There are various mentions of a general revision of the land-measurement in Egypt, but in every case it consisted of a re-determination of the areas owned or cultivated by the landowners by the ancient methods which have been described, so that there was no general control of their accuracy. While maps must show the limits of the land recorded as being owned by each person, the very vague descriptions of boundaries which alone are possible in a register render any re-measurement difficult on account of the uncertainty of the same boundary lines being adopted on each occasion.

Land is said to have been first taxed by Maimum about the year 813 A.D., and Makrizi says that the tribute of Egypt reaches 4.527.000 dinars, and was payable when the Nile flood reached a height of 17 cubits and 7 qirats,* at the rate of 2 dinars a feddan, which would correspond to a cultivated area of 2.263,500 feddans.

Ahmed Ibn Tulun measured all the land and re-distributed it.†

The historian Abdallatif ‡ states that a cadastral measurement of the land was made under the Sultan Melik el Ashraf in the year 777 A.H.

The Mamelukes established a form of land-survey which furnished a basis for assessing the land-tax, and this measurement appears to have been repeated periodically. When the Ottomans took Egypt the Sultan Selim ordered a new cadastre to be made and the yearly tribute was fixed at 600,000 piastres (each equal to 20 P.T. to-day), payable in gold when the Nile flood reached 17 cubits.§

* ARTIN, "The right of landed property in Egypt," p. 74.

† BECKER, "Beiträge zur Geschichte Aegyptens," pp. 109 and 111.

‡ DE SACY's translation, Paris, 1810, p. 156, note 17.

§ ARTIN, loc. cit.

CHAPTER V.

The Classification of Land.

Whether a cadastral survey is required to facilitate the collection of land-tax, or for the use of landowners in order that they may have a record of their property, some classification of the land has invariably to be made. The basis of this may be its value, or the purpose for which it is used, but usually both these are represented. The subject passes readily into that of land tenure, but this is too wide a field of enquiry to be dealt with in this report; the surveyor has to deal with the classification of land when indicating the boundaries of different qualities, or of portions which are allotted to special purposes, but the more strictly legal aspect does not concern him, since he is not empowered to decide in cases of disputed possession.

In early historic times it would appear that the land belonged probably to the estate of the king, by whom it was entrusted to a noble class.* There were large estates which were administered by these nobles, but we cannot now determine the conditions on which they were held. Inscriptions of the third and fourth dynasties tell of lands which were constituted as an endowment of the owner's tomb, so that from their revenue the mortuary priests might be maintained and the necessary offerings provided.† Grants of land for this, and other purposes are frequently mentioned, but no special designation of the land as belonging to special classes or categories is added.

In the twelfth dynasty the contracts of Hepzefi ‡ refer to the property which he had inherited from his father and could bequeath at will, and also to that which he possessed by virtue of his office.

Distinctions are made between certain kinds of cultivation, such as fields, gardens, and ploughed lands,§ and among the duties of the vizier, as recorded in the tomb of Rekhmare at Thebes, the regulation of

* Breasted, "History of Egypt," p. 44. This is the case in Abyssinia at the present time.
† Breasted, "Ancient Records," I, p. 89.
‡ Breasted, I, 258, and Erman, "Ancient life in Egypt" pp.145, 497, 498.
§ "Ancient Records" p. 224.

province boundaries, the limits of the lands which furnished the income of the temples, and the administration of the divisible lands held by tenants as distinguished from the indivisible tracts held by nobles are specified.* In the Harris papyrus, which gives an inventory of the total property owned by the three great temples in Egypt at the death of Rameses III, we find a distinction made between the property which had already been long in possession of the priesthood, and that which the late king had given, also the income derived from certain other properties which he had assigned yearly to these temples is included.

Temple inscriptions, texts in praise of the king, records of his successful wars and expeditions, the accounts left by nobles and great officials of their work and of the honours that had been conferred upon them, are not sources which would be likely to supply detailed information concerning the classification of land. The material which has survived from the local administrative offices is extremely scanty; still, we read of crown lands, temple property, land furnishing an annual income to the temples, land assigned to certain high offices, land leased to tenants, private property in the fertile "low land" and in the less valuable "high land," town land, canals and their dykes, gardens and vineyards, and arid lands.†

All these were distinguished and doubtless if more information were available we should find as complete a system of classification as that which existed in Ptolemaic times in the Fayum, and which has been revealed to us by the recovery of papyri from the sites of ancient towns during recent years. From these documents we find that all the categories now employed already existed at that date and doubtless had been long in existence.

The most complete collection of such papyri relating to land is that which Professor Grenfell and Dr. Hunt have published as the result of their excavations carried out in 1899-1900 at Um el Baragat, the ancient Tebtunis, on the south side of the Fayum and in the area now known as the village of Gharaq el Sultani. They date from about 120-111 B.C., and deal largely with the measurement, registration, transfer and

* Moret, "Zeitsch. für Aegypt. Sprache," 39, 36.
† "Ancient Records" IV, p. 484.

classification of land, and the taxes which were collected on it.* The village which is most fully recorded, is that of Kerkeosiris, containing 4,700 *arouræ*, or about 3,100 feddans, which in the fifty-second year of Ptolemy Euergetes II (119–118 B.C.) were distributed as follows :—

		Aroura	Feddans (approx.)	Hectares
Κώμη	Village site	$69\frac{1}{2}$	45·8	19·2
Ὑπόλογον ἄφορον	Uncultivated land ...	$169\frac{7}{16}$	111·8	47·0
Ἱερὰ γῆ..	Temple land	$271\frac{1}{2}$	179·2	75·3
Κληρουχικὴ γῆ	Cleruchic land... ...	$1,564\frac{35}{32}$	1,024·0	430·2
Παράδεισοι	Gardens.....	$21\frac{1}{4}$	14·0	5·9
Νομαὶ ἐκτὸς μισθώσεως..	Pastures not subject to rent...	$175\frac{3}{8}$	115·6	48·6
Βασιλικὴ γῆ...	Crown land	$2,427\text{-}\frac{13}{32}$	1,600·0	672·2

So that we have here all the principal divisions which have been traced in earlier times, except private property, but this area may very probably have been but recently reclaimed from the condition of waste land, having been either unsupplied with the necessary water—for it is to-day at the end of one of the supply canals—or, being an enclosed basin, it may have become water-logged from absence of drainage; in either case reclamation had probably been recent, and the land was still State property leased to the cultivators who lived in the village.

Much reclamation was taking place in the Fayum at this period and Kerkeosiris may have been but recently reclaimed from a state of desert or swamp, and for this reason was still crown property.

The office of the komogrammateus, or village scribe, whose duty it was to keep the records of the lands and to furnish returns of them to the governor of the province, has provided a large amount of instructive information concerning the categories of land at this time; it is included in the annual reports that he had to render, relating to the ownership and the cultivation of the land, as well as to the revenue derived from it. In the returns that have been preserved arithmetical errors are not infrequent, and in many cases they seem

* "Tebtunis Papyri." Egypt Exploration Fund, London, 1902.

to have been due to an intention to produce the result of 4,700 *arouræ*, whatever the correct total of the actual figures might amount to. In one papyrus the scribe Menchis admits that errors in his returns have been the occasion of reprimand from his superiors.

It is instructive to compare these classes of land with those which are recognized to-day.

The κώμη is the village site itself, which is known to-day as the *sakan*, or the area actually occupied by the dwellings of the villagers, together with the free space round it, the present *dair el nahia*. The ὑπόλογον ἄρουρα is the uncultivated land, or *bur* ; it is sometimes described as free from tax, ἐκτὸς μισθώσεως, to distinguish it from the crown lands which had gone out of cultivation, but which still had their former rent assigned to them. With the uncultivated land were also included the threshing-floors and the pigeon-houses, and probably also the canal dykes. This land belonged to the crown, but did not yield revenue, and so was classed separately from that which did do so. It thus corresponded to the public utility land of the present time but included also such waste land as was not leased to cultivators at an annual rent.

Παραδείσοι were the gardens and orchards on which a special tax was levied.

Νομαὶ ἐκτὸς μισθώσεως were pastures not subject to rent, or common land, but they probably belonged to the crown.

Ἱερὰ γῆ, or land belonging to the temples, was divided between the temples of the first rank and those of the second rank ; it may be compared with the lands which are to-day constituted a religious waqf for the maintenance of a mosque or similar building.

Κληρουχικὴ γῆ, or cleruchic land, was land held by various persons under grants from the crown ; there were seven classes of such persons who fall into three groups : the κάτοικοι, or foreign military settlers ; the civil officials ; and the native military settlers. This class of land calls to mind the lands given to the ancestor of Mes already referred to * in the days of the Pharaoh Amosis, and also those which were granted by successive governors of Egypt to their officials or followers.

Lastly, there was the βασιλικὴ γῆ, or crown land, some of which yielded rent, while other portions were uncultivated, but had a rent fixed.

* p. 18.

Land on which rent was reduced for any reason was measured and shown separately on the annual statement with an explanation. This category was a temporary one, and in time after investigation, such land was transferred to a permanent tax list or classified as uncultivated.

Another papyrus from Tebtunis gives a detailed description of certain small plots of land on the east side of Crocodilopolis Arsinoe (Medinet el Fayum) between the road round the town and a large canal, and an extract from it has been given in the preceding chapter.* The dimensions are given in *schœnia*, and the areas in *arouræ*; the plots are of the usual small size; some belong to private individuals, one belongs to the queen, another is recorded as common land, while a public road between the private property and a public canal is separately registered. The same conditions may be exactly paralleled round Medinet el Fayum to-day, and the ownership and dimensions of the plots were recorded in a manner essentially the same at this period as we meet with in the cadastral registers of 1813–1820 and 1853–1859.

From the time of the Arab conquest of Egypt the classification of land was based on the Mohammedan law, and was the outcome of the cadastral revisions which took place from time to time.† That which more nearly affects the present surveyor is the result of various changes and modifications which the viceroys of Egypt have decreed in transforming the cadastre from the conditions which existed in the eighteenth century to those which now prevail.

An extremely able summary of these changes was prepared for the use of the Commission of Enquiry ‡ which investigated the finances of the country in 1878–1880, by H.E. Butros Pasha Ghali, and it has been freely utilized in this chapter, while Yacoub Pasha Artin has discussed the subject of land-tenure and land-tax in his book, "La propriété foncière en Egypte," published in 1883 by the Institut Egyptien.

According to the Mohammedan law, "kharagi" lands are the property of the Beit el Mal or Public Domain, the cultivators having only the right of usufruct on condition of cultivating them and paying the tax "kharag"; "kharagi" thus denotes contributable lands.

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* p. 53.

† See Chapter IV, p. 55.

‡ In accordance with a resolution passed at the sitting of January 10, 1880.

The transfer of these lands by inheritance is not admitted and the heir of a cultivator cannot claim the ownership of such land, but it is disposed of by the administrator of the Public Domain as seems good, though the heirs of previous cultivators are given preference, if they are able to cultivate the land and pay the tax.

Before the time of Mohammed Ali Pasha the Government conceded its rights to nobles and officials of the State in return for sums paid for such concessions. The villages were put up to auction and knocked down to the highest bidder, who became the concessionnaire (multazim). To him was given a deed (taxit) setting forth the terms of the concession, and an order to the sheikhs and inhabitants of the village, instructing them to obey him and to pay to him the taxes. A portion of the lands of the village, known as "wassia," were reserved for his own use, and a certain sum of money was allotted to him to indemnify him for the responsibility of collecting the taxes. He thus replaced the Government and became virtually the owner of the villages and the villagers were practically his serfs.

Besides the "kharagi" lands which were thus conceded to the multazims, there was another category known as "rizqa"; these were exempt from all taxes and the full ownership belonged to the holders or to religious foundations.

Such was the state of affairs up to 1812, but in 1813 Mohammed Ali Pasha prohibited the concession of villages, and withdrew from all multazims their concessions, leaving, however, to those of Giza and Lower Egypt the lands reserved to them personally (wassia), and exempting these from tax; they further received an allowance (faiz) in place of the special tax which the villagers had hitherto paid to them. In Upper Egypt, where the multazims were in revolt, their "wassia" lands were confiscated, and added to the "kharagi" class. Other concessions which had been given to high officials, or constituted waqfs, were also taken by the Government for an annual rent, which was paid by the Pension Office (Ruznama); the "rizqa" too were similarly dealt with. These special categories no longer therefore existed in and after 1813, but their names are frequently met with as the titles of "hods" which contain the lands which were once allotted in these ways (see p. 65).

In 1813 a cadastral survey of the cultivable lands was undertaken, and they were all recorded under the name of the village to which they

belonged; at the same time they were valued and the tax that they should pay was assessed. A certain proportion of the lands of each village—4 feddans in each 104—was exempted from tax; and was allotted to the sheikhs of the villages in compensation for the services which they had to render to the Government. The uncultivated lands were omitted from the cadastre, and classed as "abadia." The "wassia" lands paid no tax, and were also omitted from the cadastre.

From this time, then, the categories of land were: "kharagi" lands on which rates of tax were imposed according to their fertility, "wassia," and "abadia."

The maximum rate of tax in Lower Egypt was 20 "mishts" of two and a quarter piastres, and in Upper Egypt 22 mishts, the minimum being 2 mishts.

In 1820 another classification was made, but there seem to have been others in 1818 and 1819 from a note on the register of Sharqia province, which refers to them; another took place in 1824, but all these seem to have been re-assessments of tax rather than any modification of the categories of land recorded in the registers.

Some years later a decree dated 11 Gamad el Awal, 1253 (August 13 1839) orders that the lands of villages whose inhabitants were unable to pay their taxes should be divided among those of other villages who could do so, and from them the arrears of tax were to be collected. This must have led to some considerable alteration of boundaries, but as no maps of village lands then existed, the changes can no longer be traced.

A decree of Abbas Pasha dated 19 Zilkada, 1267 (September 15, 1851) authorizes the sale by auction of lands which had not been included in the cadastre, and of excesses which were found in the lands occupied by cultivators, to the purchaser who undertook to pay the highest tax.

Another decree of 8 Shawal, 1272 (December 21, 1858), authorizes the sale of "kharagi" lands which had been abandoned by their occupiers as not repaying cultivation under existing conditions; these might be sold either to Egyptians or Europeans, subject to paying one-tenth of their yield to the State (Ushuri).

In the absence of maps by means of which the areas occupied by cultivators could be checked, many had encroached largely on land which belonged to the State and paid neither rent nor tax. Said Pasha, by a decree dated 28 Zilkada, 1273 (July 20, 1857) authorized any such

excess over the area recorded in the cadastral registers being given to anyone who gave information of such encroachment, provided he paid the yearly tax.

A decree of Ismail Pasha dated 1 Gamad Awal, 1282 (September 22, 1865) orders the sale as "kharagi" of cultivable lands which had not been included in the cadastre, and as "ushuri" of any abandoned or deteriorated lands.

At the time when the State Lands Survey of 1892 was commenced, the categories of land which were recorded were broadly divisible into State lands and private lands. The former included both lands of public utility, such as railways, roads, canals, etc.,* which had been declared as such by decree and could not be sold or otherwise disposed of except by virtue of a new decree removing them from this category (the Public Domain); and secondly, the rest of the State property which could be sold or leased by the Minister of Finance. Private lands were classed as "kharagi" or "ushuri," and there were also certain portions which, though owned and bought and sold, were not included in the list of property belonging to individuals; the village site was thus recorded as a whole area since no tax was imposed upon it, but the parts of it which were owned by individuals were neither delimited nor measured, nor were their areas added to the recorded area of their property, since this included tax-paying land only.

The land-register therefore showed :—

(1) the land of each landowner;
(2) the saleable land of the Government;
(3) the land of public utility;
(4) the village site;
(5) the threshing floor of the village.

The area of the last was divided among the landowners, and the corresponding tax collected from them without, however, considering them as the owners of the piece of the threshing floor for which they paid tax.

This comprises all the distinct categories of land, though special cases existed which were treated distinctly, as will be referred to in Chapter XVII, but a different division also existed which was based on the position of the land and not upon its character. The village

* See Civil Code, Art. 9.

was naturally the administrative unit, but it might vary greatly in size from a few feddans up to as much as 50,000 feddans; subdivision of the village area was therefore necessary, and it had doubtless existed from very early times. At the present day such a subdivision is known as a "hod,"* and although no special reference to such a subdivision is known in ancient Egypt, it may well have existed. In Græco-Roman times the περίχωμα seems to have answered to it to some extent, but perhaps corresponded more to the "hosha," an area surrounded by a dyke and so separated from the inundated fields, than to a normal subdivision of the village. It was probably intended originally to afford a ready means of assessing tax, the land in each "hod" being of nearly the same quality, but this character had not been maintained during the lapse of time, although a decree dated 8 Gamad el Awal, 1271 (January 27, 1855) had attempted to re-establish it in a drastic manner by raising the tax on all plots to the highest rate prevailing in the "hod."

There was no reason why the boundaries of the "hods" should not have existed unchanged for centuries, but in practice there was often considerable uncertainty in the neighbourhood of uncultivated land or where land had passed out of cultivation and had then been reclaimed after some years. Village boundaries were well known, since they represented the limits of the authority of the head of the village, and the tax on the lands enclosed by them was paid through the village; "hods" had no such guarantee of permanence and, therefore, their boundaries became in many cases difficult to locate with accuracy. This was the experience of the Commission of 1895–1896 which was appointed to assess the land-tax. The "hod" was naturally the unit, since the plot was far too small an area to deal with, but in the absence of all maps the identification of the hod limits was difficult, and the boundaries adopted became at times little more than an approximation to the ancient limits. However, this did not prevent the work from being carried out so long as it was only a question of deciding the amount of land-tax which a village should pay, but it was very different when it came to imposing a revised rate of tax on each holding in order that the amount due annually

* In Upper Egypt the word "qibala" was used, but during the present survey the word "hod" has been used throughout the country.

from each landowner might be recovered. Usually, a property consisted of several pieces of land situated in different parts of the village and bearing different rates of tax, so that before any re-assessment of tax was possible a detailed survey of the whole of the lands had to be made.

During a long series of years, as a result of numerous changes due now to superior order, at another time to the convenience of the principal proprietor, or again to any of the numerous causes which might lead to modifications, the size of "hods" had become very variable, whatever they might once have been. For a single rate of tax to be imposed on all plots in a hod, it was necessary that the quality of the land should be appreciably the same throughout, and this could only be attained by reducing the hod to a moderate size. Consequently in the revised instructions which were prepared in 1897 to facilitate the work of the re-assessment Commission, it was laid down that :—

(*a*) The area of the "hod" should be as a general rule from 50 to 100 feddans, smaller "hods" should be the exception.

(*b*) The land must be in one piece, and the cultivated or cultivable area must be as nearly as possible of one quality; the system of irrigation must be the same.

(*c*) Uncultivable land ("talif") to any extent might be included in a "hod" of cultivated land, but no land, cultivated or cultivable, in excess of five per cent. of the area of the proposed "hod" might be included which was a different quality from that of the rest of the "hod."

(*d*) The shape should be as regular as possible.

(*e*) Natural boundaries should be made use of wherever possible.

Names and numbers were to be given to the new hods thus formed, the naming being left to the village authorities; the result has been that the old names of divisions of the village have been retained for those of the new ones which most nearly corresponded to them, while new names have been allotted to the others. These new names are of course Arabic, but among the old ones are many of Coptic origin which date back sometimes with little change to the times of ancient Egypt. It is certain that these hod lists contain

many names which are to-day the sole record of villages which have long since passed away, and are consequently of considerable interest to the historian and the geographer.* Besides names of this class, there is another category of hod names of which the origin has not so far been explained; the names here take the form of a number, thirty, eighty, a hundred, etc. These are very common, while less frequently fractions such as a half, a quarter, etc., occur as names. As these names occur in early Coptic documents, fanciful explanations which attribute them to recent events in the village are not worthy of credence.

Legal expropriation of land which is required for public purposes is an introduction of recent date, for thirty years ago such land was seized by the Government when it was required. As a consequence of this, title-deeds of property sometimes include the land which at present is occupied by the older railways and canals, and though these cases usually cause but little doubt, there may be a strip of disputed land of which the landowner is constantly endeavouring to resume possession. Results of this are that the canal dykes are in some places being dug away, while in others the mud removed from the canal-bed in the annual clearings is added to the dyke, which thus tends to encroach on the fields. For the purposes of taxation only no difficulty is caused, since the tax is imposed on the land which is effectively occupied, but although the present land-registers give no guarantee of title, proprietors are not unnaturally anxious to have all land that they consider theirs by right recorded in their name, and would willingly pay tax on land which they could not for the while cultivate, if thereby they could obtain *prima facie* evidence of their right to it. This desire has furnished very numerous complaints against the Survey, which was, however, only concerned with recording effective occupation for the purpose of assessing and collecting the land-tax, and had no authority to decide in such cases of disputed claims.

* They are given on most of the cadastral maps and in the lists of revised rates of tax which were published in the "Official Journal" from 1899 to 1907 as the re-assessment of each province was completed.

The twofold classification of land which existed at the commencement of the recent survey was, therefore :—

FISCAL... ...	I. Private lands	(*a*) Kharagi (*b*) Ushuri (*c*) Untaxed (*d*) Town lands.
	II. State lands...	(*a*) Public utility (*b*) Saleable State lands.
GEOGRAPHICAL.	Provinces, fourteen in number Districts, seventy-seven in number Villages Hods Plots.	

In the cases of the two cities of Cairo and Alexandria the lands recorded in the land-registers do not account for the whole area. In the former case the registers of the Qaliubia and Giza provinces, and in the latter case those of Beheira province leave a certain amount of land, mostly built upon, unaccounted for, since no land-tax is being collected from it, but house-tax is imposed under the authority of a decree of March 13, 1884.

Riparian lands which are under the water of the Nile in flood-time, and are only wholly exposed at low stage, necessitate special treatment, since they are constantly changing, being increased in area by deposition, or reduced by erosion. They are, therefore, measured annually after the flood, and divided up amongst those who own these lands in proportion to the amount that they are recorded as owning. (Cf. ch. XVI.)

In 1884 (*) a decree was passed authorizing the sale of uncultivated lands which had not been included by the cadastre then in progress. The cadastral surveyors were required to make plans of all such lands, which were described as "Kharig el Zimam," to furnish the purchaser with a copy, and to file the original in the office of the cadastre. Most of these lands have been included in the recent survey except in the case where owners have not indicated them, or the village authorities have not pointed out boundaries so as to include them ; but in most cases the tendency was to demand that additional land on the desert margin should be enclosed within the village boundary if there was any prospect of its being reclaimed in the future. No marked boundaries existed, so that the surveyors had to be guided wholly by the statements of the sheikhs of the village. Such land, if not effectively occupied, or if no reasonable claim was established to it, was recorded during the recent survey as State property.

* 16 Zilkaada, 1301 (September 9, 1884).

CHAPTER VI.

Land Survey, 1800–1877.

When Mohammed Ali Pasha had established himself in power, and was able to turn his attention to the administration of the country, he found that a re-measurement of the cultivable lands was urgently required. As a first step, he fixed the unit of area, the feddan, at $333\frac{1}{3}$ square qassabas, as already mentioned (see p. 41), and then ordered a uniform cadastre to be carried out under the direction of Muallim Ghali, an official whose functions corresponded to those of the head of a finance department. Mengin, in his account of these times, seems to think that the length of the qassaba was at the end of the survey reduced to 3·64 metres.* This work was commenced in 1813 and was completed a few years later; it consisted, as the previous cadastres had done, of the measurement of properties, the determination of their areas, and the registration of these data and such other information as was necessary in land-registers, "gontags," for each village. But even at this time the feddan was not made uniform throughout the country, for in some places such as the provinces of Menufia and Qaliubia feddans of less than $333\frac{1}{3}$ square qassabas existed and these were left unchanged; the length of the qassaba, too, had not been officially fixed and it varied to some extent in different provinces. About 1823 an Italian engineer, Masi, was employed to prepare cadastral maps of the country and he trained a number of young Egyptians in surveying. With them he prepared maps of about sixty villages in Sharqia province on which property boundaries were shown. These are said to have been deposited in the Government offices, but no trace of them can now be found. For work of this kind a definite unit of measurement was necessary, and Mengin says that Masi used a qassaba of which the length was 3·64 metres; Lane also states that Masi gave him this value for the qassaba in use at that time. He may have derived it from those which he found in use in Sharqia at the time of his survey.

* "Histoire de l'Egypte sous Mehemet Ali." Paris, 1823, Vol. II, p. 342.

Linant Pasha * records that in 1834, when work was first commenced at the head of the Delta in order to construct a barrage, a complete scheme of irrigation was under consideration and it was then the Viceroy's intention to carry it out. In order to effect this, an accurate topographical map of the country was required and this was to be supplemented by a complete cadastral survey in the course of which maps indicating individual holdings were to be prepared. This was doubtless the result of the experimental survey made by Masi in Sharqia province, ten years before. The necessary instruments were ordered, but by the time that they arrived work on the barrage had been suspended, and the scheme for a systematic survey of the country had been shelved.

In 1840 † Mohammed Ali Pasha ordered a map of the Fayum to be prepared and this was done on the scale of 1 : 10,000 under Linant Pasha's superintendence. Preparations were made later on for measuring a base for triangulation between Abbassia and Khanka, near Cairo on the eastern desert, but nothing more was done. ‡

Between 1270–1276 A.H. (1853–1859 A.D.) by the order of the Viceroy, Said Pasha, a complete measurement of all the cultivable lands of Egypt was made under the direction of Bahgat Pasha. From a remark by Linant Pasha § it would seem that cadastral maps of portions at least of the country were made, for he refers to the cadastral maps of Beni Suef, Menufia and Gharbia, which were prepared by Bahgat Bey, but which were afterwards distributed and lost. In the villages of Upper Egypt, where the registers prepared in this survey are still in use, there is no trace of any maps, and it seems that after commencing work on a basis which included the preparation of maps, Bahgat Pasha was obliged to reduce his scale of operations and to repeat the methods of earlier times by only measuring the dimensions of holdings, computing the areas, and recording all this information in the land-register of the village together with the name of the owner, the rate of tax and other such details. The later cadastre of 1878–1888 never extended its operations to Upper Egypt ; so the survey of Bahgat Pasha of 1270–1276 A.H. (1853–1859 A.D.)

* "Mémoire sur les principaux travaux d'utilité publique exécutés en Egypte." Paris 1872, p. 381.

† LINANT, p. 492.

‡ LINANT, p. 494.

§ LINANT, p. 495.

has been the principal record of ownership since the date of its completion. It even possesses certain information which makes it more useful to the villagers than the registers of the cadastre which have just been finished, for it contains the dimensions of each holding as well as the area, whereas the registers recently prepared in order to re-assess the land-tax contain the area only, since the time at the disposal of the surveyors was not sufficient to allow them to measure and record all the sides and the diagonals of each plot, but only to take the measurements necessary for plotting an accurate plan of the holdings on a map. Since groups of parallel plots are adequately surveyed by measuring the breadth of each at either end of the plot, and their lengths at each end of the group, this procedure occupies much less time than to make complete and independent measurements of each plot, in addition to those which are necessary for locating the position of the plot in the village. Besides this, such dimensioned plans of the plots would have had no legal significance, since the Survey Department has neither the means for ascertaining who is the legal owner of the plot nor the authority to decide disputed cases which may arise.

In consequence of containing information relating to the dimensions of each plot, the cadastral registers of Bahgat Pasha's survey are still in general use in Upper Egypt wherever basin irrigation prevails, and the land has to be laid out annually; where perennial irrigation has been introduced recently, the present maps and registers will rapidly supersede them. At the time of Bahgat Pasha's survey the feddan had already been defined as containing $333\frac{1}{3}$ square qassabas, but the length of the qassaba itself was more uncertain for it had not been yet laid down by any competent authority. It was at this time shorter than that of 3·64 metres which Masi had used in 1823 and approximated to 3·50 metres (see p. 39), at any rate in Upper Egypt. As an instance of the method employed in the land-registers of this cadastre, an extract is given here from the entries relating to the "qibala" or "hod" of *Gharbi el Tariq*, which formed a part of the village of Sohag in Upper Egypt,* which may be compared with the description of a portion of Crocodilopolis Arsinœ (Medinet el Fayum) given on page 53 from a papyrus of Ptolemaic date.

* From an Arabic copy, communicated by Mr. H. G. SKILL.

(Translation).

Praise be to God.

By God's will may this book containing the survey information about lands in Sohag Village, Girga Province, be blessed. Under the superintendence of Ali Eff. El Darwish, Moawin of the province; entries by Hanna Nakhla of Tema and Eqladios Nakhla of same village and Said Bishai of Sohag; chainmen Mbarak Botros and Habashi Abd el Malak of the village. Indications furnishep by the "dallal" Ayub el Kholi of Sohag in 1276 A.H.

Qibalet Gharbi El Tariq.

	I.	II.	III.	IV.
	Ahmed Pasha Rashed (by Gift)	Ibrahim Mannaa	Ahmed el Arif and Moh. el Arif.	The before-mentioned.
Dimensions	63½ 39 61 41	63 5¼ 63 5¼	65½ 20¼ 63 27 13/24	22 35 27¼ 34⅔
Mean... ...	62¼ 40	63 5¼	64⅔ 23 13/48	24⅝ 34⅚
Product:	2,490	334	1,544	857
	F. Q. S.	F. Q. S.	F. Q. S.	F. Q. S.
Equivalent:	7 11 8	1 0 0	4 15 4	2 13 16
Deduct Bur* new canal. in the Gift.		Bur new canal.	Bur new canal.	Bur new canal.
Dimensions	41 8⅔ — 11	11 5 — —	20¼ 11 — —	35 11 — —
Mean... ...	41 9⅚	11 5	20¼ 11	35 11
Product:	403	58	223	385
	F. Q. S.	F. Q. S.	F. Q. S.	F. Q. S.
Equivalent:	1 5 0	0 4 4	0 16 0	1 3 16
Net:	6 6 8	0 19 20	3 23 4	1 10 0

	V.	VI.	VII.
	The before-mentioned (Bur canal).	Ibrahim Hagga.	The before-mentioned.
Dimensions	14 101 13 98	10 16 11 16	12 10 12 11
Mean... ...	13 100	10 16	12 10
Product:	1,354	176	128
	F. Q. S.	F. Q. S.	F. Q. S.
Equivalent:	4 1 12	0 12 16	0 9 4
	Cultivated by Ahmed and Mohammed el Arif.	Sharaqi lands.	Sharaqi lands.
	F. Q. S.	F. Q. S.	F. Q. S.
Deduct:	1 2 0	0 1 8	0 0 16
Net:	2 23 12	0 11 8	0 8 12

	VIII.
Ahmed El Arif and Mohammed El Arif	land owned in shares without boundaries being determined.
Dimensions	3 28 2 —
Mean	2 28
Product:	71
Dimensions	2 39 — —
Mean	2 39
Product:	78
Dimensions	2 15 — —
Mean	2 15
Product:	31

	F.	Q.	S.
Equivalent: Square Qassabas 180 =	0	13	0

* Uncultivable land.

IX.

Ibrahim Hogga.

Dimensions	9	16·5
	10	17
Mean... ...	9½	16
Product:	159	
Equivalent:	F. 0	Q. 11 S. 12

X.

Badawi Hogga.

	10	22
	9	22
	9	22
	214	
	F. 0	Q. 15 S. 8
Deduct Bur Gisr:	0	0 20
Net:	0	14 12

XI.

Ahmed el Kebsh Bur Sharaqi.*

	11	15
	10	17
	10	16
	171	
	F. 0	Q. 12 S. 8

XII.

Abdel Kerim Bezada

Dimensions	8	3
	9	—
Mean	8	3
Product:	26	
Equivalent:	F. 0	Q. 1 S. 20

XIII.

Land owned in shares without boundaries being determined.

103	3	28	3	94	3·5
—	2	—	—	—	—
103	2	28	3	94	3·5
57		84		329	

670 = F. 2 Q. 0 S. 8

XIV.

Abdel Kader Abu Doh

Dimensions	10	10·5
	8	10
Mean	9	10
Product:	92	
Equivalent:	F. 0	Q. 6 S. 16

The dimensions are given in qassabas, and the product in square qassabas which are converted into feddans, qirats and sahms.

* Unirrigated land.

In 1858 the question of a general map of Egypt was again taken up, and the Viceroy Said Pasha appointed a commission to study the subject and to carry out the work. On its recommendation, geodetic instruments of the best type then made were ordered from the firm of Brünner, of Paris; they consisted of one 4-metre base-bar which was composed of a bar of platinum and another of brass, mounted on an iron support of T-shaped section (this apparatus is described in Chapter XI); two geodetic theodolites with circles of 40 centimetres in diameter, and furnished with four microscopes on both the vertical and horizontal circles; another instrument of the same type but without the horizontal circle, was also bought for use as a portable transit instrument.

A series of experiments were carried out at Paris in order to determine the coefficients of expansion of these metal bars, and subsequently elaborate comparisons were made at Madrid with another base-bar of the same type which belongs to the Spanish Government. The bar was brought to Egypt about 1867, but was not, so far as I can ascertain, ever taken into regular use. Linant Pasha states * that when the base-bar did arrive from Paris, it was not even unpacked, but was allowed to lie in its box until Sir David Gill made use of it to measure a short base near the Pyramids of Giza in 1876. Later, another base is said to have been measured along the road to the Pyramids under the direction of General Stone, of the Egyptian General Staff, but I have been unable to trace any account of this. I am assured, however, that in neither case were the observations ever fully worked out, and that these bases were never used in the survey of the country; the bar itself was forgotten until a few years ago, but at the present time it is the principal standard of length with which all others in the country used by the Survey Department are directly or indirectly compared (see Chapter XI).

While Ismail Effendi Mustafa † was sent to Paris to study astronomy and to superintend the construction and verification of the base-measuring apparatus which had been ordered, Mahmud Bey ‡ was put in charge of the surveying work in Egypt, and was instructed to

* *Loc. cit.* p. 493.

† Afterwards Ismail Pasha el Falaki.

‡ Afterwards Mahmud Pasha el Falaki.

prepare a map of the country. But these elaborate preparations for work of a high quality were soon abandoned and Mahmud Bey received but little support or encouragement in his work. On a map of the Delta, which was published some years later on a scale of 1 : 200,000, it is stated that when he commenced to survey the country, neither a base-measuring apparatus nor theodolites of precision existed; he therefore determined the latitude and longitude of about thirty points in the Delta, and of others in Upper Egypt, by means of a sextant and chronometers. The detail was surveyed by means of plane-tables used by surveyors who traversed the banks of the Nile and of the principal canals with them, and located the villages by intersection. A note on the map of Gharbia province states that the latitude and longitude of fourteen towns were determined and used as a control. In Upper Egypt the same method was adopted, though there is no record of the places whose geographical positions were then astronomically determined. Thus the original scheme for a complete cadastral survey had been wholly abandoned; a certain amount of approximate surveying was done, which provided material for some small-scale topographical maps but did not reach a higher precision than that of reconnaissance work; canals and villages were shown and but little else, so that while they were of some use for administrative purposes in a country where no other maps existed, they did not facilitate the control of the land-tax nor did they assist landowners to maintain a record of their lands. Only a few of the maps were ever published, viz., a map of the Delta on the scale of 1 : 200,000 in 1871, those of Qaliubia, Menufia and Gharbia provinces in 1871 on the scale of 1 : 100,000, and one of Alexandria and the surrounding country on the scale of 1: 50,000; this last map only was controlled by triangulation. The originals of the maps of Upper Egypt which were drawn to the scale of 1 : 25,000 are in the Map Store of the Survey Department, and bear the dates of 1871 or 1872: they are purely topographical and indicate neither village nor district boundaries.*

* Cf. LYONS, "Topographical Surveying in Egypt." Survey Department, Cairo. 1909 (in the press).

The approximate areas of cultivated land as determined by the different measurements which were made between 1800 and 1877 are given by Yacoub Artin Pasha :—*

Year.	Feddans.	Remarks.
1813	3,054,716	The qassaba was then 3·64 metres in length. —Clot Bey.
1840	4,491,226	
1852	4,160.169	
1863	4,395,303	
1875	4,703,456	

In all these measurements the feddan contained 333 $\frac{1}{3}$ square qassabas except in the special cases which have been referred to ; the qassaba had a length of 3·64 metres in 1813, of about 3·50 in 1840 and 1852, and was fixed at 3·55 metres in 1861 by decree.

Clot Bey gives the cultivated area in 1840 as being made up as follows :—

		Feddans.
Kharagi lands in	Lower Egypt	2,249,000
	Middle „	856,826
	Upper „	750,400
Shiflik and abadia lands	... ...	635,000
	Total...	4,491,226

Boutros Pasha Ghali gives 3,525,169 feddans as the area of the kharagi lands in 1852, and if the same number of feddans are added for the shiflik and abadia lands as given by Clot Bey in 1840, we obtain a total area of 4,160,169 feddans.

* "The right of Landed Property in Egypt." London, 1885. p. 219 ; and "Mémoires de l'Institut Egyptien," Cairo, 1907.

With these values may be compared the total area of about seven and a half millions of feddans of cultivable land measured by the present survey. (See chapter X).

This period is of considerable interest, for although no complete survey in the modern sense of the term was accomplished, it was fully realised that a better system of measurement was desirable, and that until maps existed on which the position, shape and size of each holding were shown, no real improvement of the system of taxation could be introduced. The difficulties which prevented its achievement were mainly a want of continuity in policy, for schemes were initiated only to be abandoned a few years later, and the absence of an organization such as would enable those who understood the principles of surveying to form a staff capable of carrying out the various operations. Individuals worked zealously, but such exertions were intermittent, and no systematic scheme was ever devised and then steadily adhered to.

CHAPTER VII.

The Cadastre of 1878–1888.

An inquiry into the state of the finances of Egypt having become necessary, a Commission was instituted by the Khedivial Decree of January 27, 1878, in order to verify the deficits in various accounts and to estimate the available revenue.

In the course of their enquiries it soon became evident to the members of the Commission that the land-tax could not be effectively studied until not only the area of each property was accurately known, but also the size and position of the various holdings of which it was composed. The measurements made under Bahgat Pasha in 1853–1859 furnished only the areas of holdings, and these areas, as we have seen in the previous chapter, depended on a qassaba which differed in length from that which had been legalized in 1861, and also on a system of computation which was incorrect, and which might introduce errors of considerable magnitude.* All the cadastral operations in the past had consisted in compiling lists of the lands in each village, and entering in them the areas of the various holdings which were obtained from such measurements and computations as these. The results of one such compilation might be compared with another, and differences enquired into, but no efficient control could exist until each plot of land was not only measured but also located, and its position with reference to the surrounding plots indicated, which could only be done by the aid of large-scale maps.

In Egypt, where rain does not furnish the moisture which vegetation needs, the position of a piece of land is of special importance. Fertile fields have no value unless they are within reach of a canal or one of the smaller water channels which distribute the water of the Nile, while a landowner who is more favourably situated than another can often interfere with the supply of his neighbour. Low-lying lands vary in value, and if not sufficiently drained may be almost valueless. This important factor, location, cannot be effectively represented in land registers, and

* See Chapter III, p. 43.

the only check upon the correct valuation of a plot or the rate of tax imposed upon it, is by a re-examination of the classification in the field, which may be a long and expensive operation. By using maps on which each holding or group of holdings has been plotted to scale, any anomalies in the rate of tax are at once evident and can be enquired into; any lands which are under reclamation can be indicated and re-assessed from time to time; and the same plot will not be recorded twice over in the names of different owners. The measurement of holdings and the calculation of their areas may provide sufficient means of collecting taxes due to the Government, but maps are both a safeguard and a great convenience to the landowners in dealing with their property.

One of the first requirements, therefore, was a cadastral survey which should employ correct measures and accurate methods in order to locate the various properties, to determine the correct size and shape of each, to record the same together with the name of the owner, and to prepare maps to show the position and shape of each plot.

In accordance with the recommendation of the Committee of Enquiry a cadastral survey was authorized by the decree of February 9, 1879, Mr. A. Colvin * being appointed the Director-General. He, however, retired in April of the same year, and was succeeded by General Stone, who was appointed Director on April 13, 1879. During his period of direction, technical operations were commenced under the authority of a decree of August 10, 1879, which defined the limits of the surveying operations, and directed that in order to ensure a fair division of the land-tax among landowners, a survey was to be made of the lands in Upper and Lower Egypt, as well as a classification of them. The original documents were to be preserved in the archives of the Ministry of Finance while one copy was to be deposited at the Mudiria and another at the office of the cadastre. The registers and plans were to be accessible to the public, and copies were to be supplied on payment of a fee. This provided for a complete cadastral survey which should not only measure and prepare maps of the country but also possess the necessary means of accurately recording landowners' titles to land and of establishing a more efficient system of registration than had hitherto existed.

* Afterwards Sir Auckland Colvin, K.C.B.

At first the survey appears to have been carried on in a somewhat tentative manner ; no definite regulations seem to have been issued to the surveyors, so that each of them could follow his own view as to the most suitable method to employ. The elaborate base-measuring apparatus and the geodetic theodolites which had been purchased ten years before were not utilized, probably because the time that even a second order triangulation would have occupied was considered to be a serious objection to employing it ; unfortunately, the usual practice of having a network of accurate triangulation to control and form the basis of the detail survey was only partially adopted, probably on account of the urgent necessity for completing the work as soon as possible, but the disadvantages of dispensing with such a control and employing an inferior class of triangulation soon became evident. Numerous errors were found when a systematic verification of the work was commenced, which would have been detected during the progress of the work if a well-connected and accurate triangulation had existed and if the observations had been subjected to independent computation and criticism.

Work was commenced at several points in the provinces of Qaliubia, Beheira and Gharbia, but, in the absence of any systematic control, reliable results were hardly to be expected. No records remain to show what general scheme of operations was intended, but the survey of numerous areas of moderate size, rather than a single plan of survey which would embrace the whole country, seems to be indicated. The 4-metre bar which Brünner of Paris had made and which Sir David Gill had used near the Pyramids of Giza in 1876 in measuring a base, was not employed in the survey of the country at this time although its length had been carefully ascertained by comparison with other standards both at Paris and Madrid. Instead of utilizing it, two steel triple-metre bars were purchased in Italy which were presumably intended for controlling the wooden rods which were used for measuring the bases; but as each of these wooden rods was four metres long, the verification of them by means of the three parts of the triple-metre was a troublesome operation and was soon abandoned.*

* See Chapter XI.

No very definite information exists about the technical methods employed at this period but it is evident that the work was too uncontrolled to be reliable. Hitherto all land-measurements in Egypt had been made by means of the qassaba rod, but now for the first time the 20-metre chain was employed and was regarded with but little favour by the cultivator, who did not understand it and mistrusted the results obtained; this doubtless increased the difficulties of the survey. It was soon found necessary to study the conditions of work somewhat more closely if satisfactory results were to be obtained, and in order to effect this a decree dated December 27, 1879, appointed a Commission to enquire into the work of the Cadastre, since the necessity for a more thorough organization and more systematic checking of the work was recognized.

General Stone retired from the Khedivial Service in April, 1880, and the direction of the Cadastre was confided to a Committee appointed by a decree of April 7, 1880, and consisting of :—

Mohammed Pasha Rustem.	Rousseau Bey.
Mahmud Bey el Falaki.	Mr. A. Colvin.

The first act of this Committee was to institute an examination of all the surveying which had been accomplished during the preceding twelvemonth, and both the triangulation and the detail survey of the villages and holdings were tested in the three provinces of Qaliubia, Gharbia and the Fayum where work had been already commenced. The Committee in their report for the year 1880 * draw attention to the inaccuracy of the work and state that in Gharbia the triangulation was inaccurate and insufficient to control the cadastral survey of the individual holdings ; in Qaliubia 30,000 feddans (12,600 hectares) had been triangulated but no checking was possible, since the observer had rarely marked his stations permanently. In the Fayum. only some preliminary work had been done and no triangulation had been observed. In some other provinces a little had been done, but the amount was insignificant.

* Cairo, 1881.

The result of the verification which was carried out in the latter half of 1880 was as follows :—

Province.	No. of villages under examination.	No. of villages rejected.	No. of feddans rejected.	No. of feddans accepted.	Total feddans.
Qaliubia	26	3	39,500	30,000	69,500
Gharbia	3	2	1,415	18,000	19.415
Beheira	—	24	16,686	—	16,686
Total	29	29	57,601	48,000	105,601

Besides the examination of what had already been done a certain area was surveyed under the new organization and the state of progress at the end of the year 1880 was reported to be as follows :—

AREA IN FEDDANS.

Province.	Surveyed up to April and accepted.	Surveyed April to December.	Remaining to be surveyed.	Estimated total area of province.
Qaliubia...	30,000	16,664	106,175	152,839
Gharbia...	18,000	57,696	789,094	863,332
Fayum	—	18,700	204,675	223,375

For the last six months of this year the cost of the work is given as follows :—

Gharbia : 55.821 feddans surveyed for L.E. 63.136. or L.E. 12 per 100 feddans.

Fayum : 14,356 feddans surveyed for L.E. 2,453, or L.E. 17 per 100 feddans, but in these totals the cost of the triangulation is not included.

Therefore, up to the end of 1880, 198.661 feddans had been surveyed since the Cadastre had been commenced, at a total cost of L.E. 79,379, or L.E. 40 per 100 feddans, which rises to L.E. 56 if the 57.601 feddans of rejected work are omitted, corresponding to a cost of L.E.0·95 and L.E. 1·33 per hectare. The purchase of instruments, etc., and the

delays inseparable from starting a new piece of work are partly accountable for this high figure, but the cost was undeniably very high.

The work was now divided into three operations: triangulation, delimitation of village boundaries, and detail survey; these were carried on in three provinces, Gharbia, Qaliubia, and Fayum by means of 77 survey parties which were distributed under six inspectors; each party consisted of a surveyor, an assistant or apprentice, and four chainmen, but in many cases an assistant was not available.

The distribution was as shown in the following table :—

Province.	Triangulation.		Delimitation.		Detail Survey Party.
	Inspectors.	Survey Party.	Inspector.	Survey Party.	
Gharbia	1	6–8	2	4–6	35
Qaliubia	1	2	1	2	13
Fayum	—	2	1	1	12

The Committee, in the report on the Cadastre for 1880, record that it had been found necessary to work on different lines in the province of Gharbia on the one hand, and in those of Qaliubia and the Fayum on the other. The staff employed varied greatly in training and technical knowledge, so that it was considered preferable under the circumstances to give up the idea of making a general triangulation of the country which should be of similar character and consistent throughout, and to proceed instead on more restricted lines. In order to carry out this decision, a network of triangles, having a mean length of side of 4 kilometres, was to be observed in the provinces of Qaliubia and the Fayum, which might later be extended to other provinces. Each of these major triangles was to be divided into four minor triangles the angles of which would furnish points to control the traverse lines laid down by the parties who delimited the village boundaries in advance of the detail survey.

Thus the minor triangulation in these provinces was to be based upon the major, and according to first arrangement each of the larger triangles was to be divided into four small triangles by joining the centre point of each side to that of the next side in order to avoid the necessity of observing more angles than it was absolutely neces-

sary to measure. But this method was found to be impracticable and was replaced by another scarcely more satisfactory; a side of a large triangle was divided into four parts, each part being chained twice, and these lengths were used as bases for the minor triangulation. Discrepancies between the length of the large side, as obtained by such measurement, and its calculated length, do not seem to have been considered, if they were not large enough to necessitate re-measurement; indeed it does not seem that there was any central office for dealing mathematically with such questions. Later on this method too was discarded, and the triangulator carried on the minor triangulation from any point which had been determined by the major triangulation. The triangulation of these two provinces was in charge of a special inspector, but in the province of Gharbia it was under the inspector in charge of the survey of the district.

This province of Gharbia was divided amongst three inspectors, each of whom directed the triangulation, the delimitation of village boundaries and the detail survey within his area. These areas were bounded by natural features, *e.g.*, railways, river arms, or main canals, and were surveyed independently of each other. First of all each area was divided into units of from 5,000 to 6,000 feddans, each of which formed a separate piece of work, and was covered with a small triangulation of an elementary character, which was to control the plane-table and chain survey which followed. The scale of the maps was 1 : 2,000, and the permissible error in length was laid down as being not greater than 3 per 1,000. From the regulations which were issued at this time for the guidance of the surveyors, it is possible to form an idea of the general plan on which it was now proposed to make a cadastral survey of the cultivable lands of Egypt.

Triangulation.

For the so-called major triangulation, of which the triangles were about equal in size to those of a third order triangulation of the present time, a base was measured in Beheira on the Rahmania railway, another at Nawa in Qaliubia on the Qaliubia-Zagazig line, and a third near the village of Sonbat in the Fayum, so that these three bases formed the foundation of the survey of these provinces. Each base-line was laid out with a theodolite along the railway embankment, and at a distance of about two metres from the rails; wooden pickets 0·10 metre

by 0·10 metre in section were placed at intervals of four metres apart and carefully aligned, being sunk into the ground until their heads were about 0·60 metre above the surface of the ground. They were made as level as possible, but no special determination seems to have been made in order to correct the final length for dislevelment of the rods. The measurement was made by placing three 4-metre oak rods successively on the pickets until a section of 204 metres had been completed by placing seventeen sets of three rods. The end of the last rod was then transferred to the ground and compared with a metal dot set in a block of stone, which had been built into a masonry pier and placed in the alignment in order to mark the end of the section. Ten of these sections made up the 2,040 metres of the base, and each section was measured once in each direction in the forenoon and once in each direction in the afternoon, being thus measured four times in all; the procedure was repeated the following day, making a total of eight measurements. Nearly a month was occupied in measuring the whole base, and the work done was sufficient to furnish results of a fair precision. Very good results are obtainable with well-seasoned wooden rods if carefully used and regularly verified, but, so far as can now be ascertained, the verification of the length of the oak rods in this work left much to be desired. These rods were five or six centimetres square, and were made of old well-seasoned oak, being furnished at either end with steel heads. In order to present as small a point of contact as possible, part of these steel heads was cylindrical in shape, the cylinder at one end of the rod being horizontal, while that at the other end was placed vertically; by this means the contact between two rods was formed by two of these cylindrical surfaces meeting so that the axes of the cylinders were at right angles to one another. It was found inconvenient to verify the rods, which were four metres long, with the standard triple-metre which had been purchased in Italy, so that in practice the length of the rods was controlled by means of a steel tape; no complete records exist of the measurement of any base, so it is not possible to determine the accuracy actually attained, and although the tape is said to have been of standard length and to have been corrected for temperature no detailed information on these points is given. Each rod was measured with this tape before and after each day's work.

After the measurement of the base, the triangulation was taken in hand, and the angles were measured with 12-inch theodolites made by Troughton and Simms, which were furnished with verniers on both the horizontal and vertical circles by means of which angles could be read to 5″ and 10″ respectively. Two readings were taken with the vertical circle facing right, and two more after the telescope had been reversed, but no change of the zero of the circle was made, so that these four readings constituted a complete observation.

All three angles of a triangle were supposed to be measured, but there is evidence that this rule was often disregarded.

Triangulation was carried on in this way in the provinces of Beheira, Qaliubia and the Fayum, but as each of these was separated from the others by a considerable distance, no junction could be made in order to check one network by another; nor, so far as can be ascertained now, was any base of verification measured in any of these provinces.

The second class of triangulation, which was executed in the province of Gharbia by a less expert staff, furnished an even less stable foundation on which to build up a cadastral survey which was to be plotted to the scale of 1 : 2,000. Bases were measured two or three times with a chain along a railway line or a canal bank, and on these a network of small triangles were built up, their sides being from 800 to 1,200 metres in length. The angles were measured with 6-inch or 8-inch theodolites, and from these observations the lengths of the sides were calculated in the field; the co-ordinates of the points thus fixed were not determined nor was any general control exercised by means of independent computation.

Computation.

Indeed, there is little doubt that nothing of the kind was attempted since there was no independent mathematical discussion of the observations nor any systematic distribution of errors. All the computations were made by the observer in the field, so that it was within his power to modify observations which seemed to be unsatisfactory and to record the third angle of a triangle without observing it. The calculations were only carried so far as to give the lengths of the sides,

and the co-ordinates of each triangulation point with reference to a point of origin were not computed. Throughout the work plane trigonometry alone was used and the sphericity of the earth was neglected. In single villages this was not of importance, but, when the attempt was made to combine the results to form maps of districts and provinces, appreciable errors were introduced by this omission.

The surveyors took the points determined by the triangulation and proceeded to fill in the topographical detail, and the property boundaries with chain and cross-staff, the measurements being plotted directly on the map-sheet. When plots were very small they were instructed to make special dimensioned sketches on a larger scale than 1 : 2,000, which was that employed for the maps.

In 1881 the organization of the Cadastre was improved but without introducing any modifications which would have led to a more accurate form of triangulation. In Gharbia, for example, marks were placed along the village boundaries and the area thus enclosed was divided up into map-sheets, so that a separate group of map-sheets on the scale of 1 : 2,000 was prepared for each village; the triangulator worked so as to fix about two points for each field sheet which contained about 240 feddans, a very ineffectual control of the chain-survey as compared with the fourteen to eighteen points which are now provided by triangulation and theodolite traverse for an area of about 120 hectares or 285 feddans, which is plotted on a somewhat smaller scale, viz., 1 : 2,500; the triangulation in neighbouring villages was connected, but it was of insufficient precision to be an effective control. The maps when completed were returned to the Central Office in order that the areas of the holdings might be calculated, for which purpose their dimensions were taken off the map-sheets; after which they were returned to the village in order that the land-registers might be written, the classification of lands carried out, and the tax fixed.

During this year the examination of the villages which had been surveyed in 1879-80 was completed, and the work in forty-six villages was rejected.

By the end of 1881, the area which had been surveyed or was under survey, was reported to be as follows :—

	No. of villages.	No. of feddans.
Completely finished	140	212,638
Awaiting final verification	15	27,867
Under survey	47	36,421
Triangulated and delimited	52	63,033
Triangulated	14	12,981
Triangulation marked but not observed	103	—
Being marked...	21	—
Total... ...	392	352,940

Of this total, 53,509 feddans had been completed in the course of 1880, leaving 299,431 feddans as the area which was surveyed in 1881, and was in course of being surveyed at the end of the year.

This area in feddans which had been surveyed was distributed as follows :—*

Province.	Surveyed up to 31 12 1881.	Remaining to be surveyed.	Total.
Gharbia	234,412	628,910	863,332
Qaliubia	28,750	124,089	152,839
Fayum	37,052	186,323	223,375

But some 426,000 feddans belonged to the State Domains, only half of which was to be surveyed by the Cadastre, since the Administrators of the State Domains had undertaken the survey of the remainder. Menufia province (Tala district) was also commenced in this year, since it was situated near Tanta and, therefore, the work could be supervised by the inspectors there.

At this time the estimated area of the cultivable lands in Egypt was 5,738,000 feddans, of which 515,000 feddans had already been,

* This total area surveyed, viz., 300,214 feddans does not agree with the area in the previous table, and is apparently derived from about 268 villages of which 113 were only partially completed; for these only one-third of their area is included. See "Rapport sur les opérations du Cadastre pendant l'exercice 1881." Cairo, 1882.

or were about to be surveyed by the Commission of the State Domains, thus leaving 5,223,000 feddans to be surveyed by the staff of the Cadastre, and this, it was estimated, could be completed by 1894 at the rate of 500,000 feddans annually.

It was now proposed to prepare maps of each district on the scale of 1 : 40,000 as soon as the cadastral maps were completed by reducing them to one-twentieth of their original scale ; the districts of Kafr el Sheikh and Samanud in Gharbia were to be the first to be so treated and their maps were to be printed and published as soon as the cadastral map-sheets were ready.

With the introduction of a better organization it became possible to arrive at a more exact estimate of the cost of the work and the Committee give in their report for 1881 :—

Expended up to 1st January, 1881	L.E.	79,279
„ during 1881	„	57,452
Total	L.E.	136,731

For this sum maps of 302,000 feddans* had been prepared at an average cost of L.E. 44 per 100 feddans, but additions have to be made to this amount for areas not yet computed, and lands not yet classified ; on the other hand the expenses of purchasing instruments and training staff, which must necessarily be heavy at the commencement of such work, raise the average cost unduly. Moreover, if the cost of the work which was done in 1879 and 1880 and accepted as sufficiently correct is taken into account, the average rises to L.E. 148 per 100 feddans. On the other hand, taking the actual cost of the field survey in 1881 only, and omitting that of the classification of lands, the cost works out at L.E. 21·7 per 100 feddans in the first quarter of the year, L.E. 13·47 in the last quarter, and in Gharbia it fell to L.E. 8·4 in some parts, which is noted as being less than that of L.E. 6, the cost per 100 feddans of the topographical survey which the Commission of the State Domains was carrying out, since the amount of detail plotted by the Cadastre was much greater. Incidentally, it is also recorded that the average size of a plot in the parts which had been surveyed was 2·5 feddans. It was estimated that after another year's work the cost of the field survey alone would not be more than L.E. 9 per 100 feddans.

* See footnote on preceding page.

The staff employed at the beginning of the year 1881 consisted of about a hundred and forty surveyors besides inspectors, but this number was increased by about forty by the end of the year, thus raising the number of the field-survey parties to sixty-two. The distribution of the parties was as follows :—

Parties for	January, 1881.	January, 1882.
Triangulation	13	7
Delimitation	7	8
Field survey	42	62

Of the surveyors or heads of parties, more than one-third were at this time Europeans.

In order to increase the out-turn of work, payments were made in proportion to the amount of work done, by which the salaries of most of the employees were almost doubled. Though the amount of work done increased considerably, there was naturally a great falling off in the quality of it, and two years later the system was suppressed.

In 1882 the work was carried on after the same system, but it was much interrupted by the rebellion and by the events connected with it ; still, nine months' work was done and 170,000 feddans were surveyed, the areas of holdings comprising 178,000 feddans were calculated, and 13,000 feddans of land were classified in the provinces of Gharbia, Qaliubia and the Fayum to which the survey was still limited.

Transfers and retirements had changed from time to time the constitution of the Committee of Direction, until finally it was suppressed in March, 1883, and the charge of the Cadastre was entrusted to Mr. Gibson. In this year, too, the budgetary provision was reduced from L.E. 60,000 to L.E. 35,000, and a considerable reduction in staff was thereby necessitated ; the staff which was employed in 1882 and 1883 was as follows :—

Year.	Inspectors.	Sub-Inspectors.	Surveyors.	Assistant Surveyors.	Draughtsmen and clerks.	Chainmen.	Total.
1882	5	3	74	93	94	449	718
1883	3	1	48	75	42	256	425
Reduction...	2	2	26	18	52	193	293

In all, sixty-eight Europeans and thirty-two Egyptians were dismissed, besides a hundred and ninety-three chainmen.

Before the suppression of the Committee of Direction several modifications of procedure had been proposed and discussed, and these were brought into regular use in the first half of 1883. Instead of calculating areas in a central office from the maps, the dimensions of the plots were in future to be booked in the field and the areas computed from them there, by which means the areas could be compared with those of the village tax-register and with the title-deeds of the owners.

The earlier procedure of determining the area in the Central Office, some time after the field work had been finished, by means of measuring the holdings with a scale and controlling the results with the planimeter, was slow and unsatisfactory. Expansion and contraction of the paper caused errors ; much was left to the care of the surveyor, and errors made by him could not be controlled * ; the areas of holdings were not available at once for comparison with the taxation-list of the village, so that a valuable check was not utilized ; and finally, if a sheet was lost or damaged the work had to be done again since no other record existed.

By recording the measurements made with the chain, areas could be computed on the spot, and the results compared, if need be, with the taxation-list or with the owner's title-deeds ; the method of direct measurement was understood by the landowners who were, therefore, more inclined to place confidence in the results than in those of the plane-table triangulation which they could neither understand nor check.

The plane-table was in future only to be used for fixing the principal points on the boundaries of the " hods " in large properties and villages, while individual holdings were to be measured with the qassaba rod, or with the chain and cross-staff only. The new method of recording all measurements demanded more time, but work was reduced in other ways, for since the area of holdings was no longer to be computed graphically from the maps but from calculations based on measurements directly made on the ground, the accuracy of the area no longer

* In the recent survey graphically measured areas had to be employed but they were controlled by independent computation of area based on the triangulation and the theodolite traverses (see chapter XV).

depended solely on the accuracy of the maps; the maps were to be but plans on which the relative position of the holdings could be seen and were not to be considered as sufficiently exact to determine the area of each plot. It was, therefore, decided to reduce the scale of the maps from 1 : 2,000 to 1 : 4,000, field-books being kept in which all measurements were recorded. This reduction of scale enabled a considerable economy to be effected since the area of maps to be drawn was greatly reduced, a map on the scale of 1 : 2,000 being replaced by one of one-quarter the size on the smaller scale of 1: 4,000.

At the same time, the system of paying gratuities in order to obtain an increased amount of work was definitely abandoned.

These changes were decided upon at the beginning of the year, and all villages commenced after this date were surveyed under the revised system; those already in hand were completed under that which had hitherto been in force.

During this year work was continued in Gharbia, Qaliubia, and the Fayum, and was commenced in Menufia, a considerable area being completed as shown in the following table :—

	Feddans.
Triangulation	251,030
Detail survey completed	179,890
Detail survey in hand	61,556
Area calculated	95,392
Area under calculation	59,382
Area calculated in Central Office...	122,461

The area shown as being calculated in the Central Office represents that which was in hand under the old system at the beginning of the year.

In consequence of the reduction of expenditure in all branches of the Government service the provision for the Cadastre, which had been L.E. 60,000 in 1881 and 1882, was reduced in 1883 to L.E. 35,000, and of this a sum of L.E. 1,668 was expended in determining the damage done to property by the fire at Alexandria in the previous year; the effective sum available this year for surveying was only L.E. 32,880. The appearance of cholera in this year hindered the work considerably, and non-attendance of the landowners as well as the village authorities caused much loss of time. This unavoidable reduction of funds greatly crippled the work of the survey, and as no thoroughly satisfactory system of triangulation had been established in the previous years

when more money was available, it was impossible to introduce it with reduced funds, and when reorganization throughout the country was making increasing demands for detailed measurement of land. From this time onwards more and more surveying in provinces other than those in which the regular work of the Cadastre was in hand was required each year.

In the regulations for the Cadastre which were published in 1880, certain rules were laid down for the compilation of the land-registers. They were to be based on the actual possession, and no reference was to be included of claims to property which was not effectively occupied. The land was to be recorded by the number of "hods" and plots as shown on the maps. Provision is made for "hods" which, though included among those which belonged to the village, nevertheless were not shown on the map; perhaps because they had been removed by the erosion of the river, by being incorporated into another village, or for other reasons. Such were to be entered without a number in the register, with the remark that they could not be located on the ground. The owner's name and that of his father were recorded as well as the owner's domicile. When several individuals owned the same property it was recorded in the name of him to whom the tax-receipt was made out, a statement being added that he owned it in share with other co-heirs. Land which was uncultivated or abandoned and to which no claim was established was to be recorded as Government property. A note was made of any land which had not been cultivated for three years. Such registers were summarized to show the area of cultivable lands and uncultivable lands in each village in the form which is given here:

TOTAL AREA OF THE LANDS IN THE VILLAGE OF

CULTIVABLE LANDS:			NON-CULTIVABLE LANDS:					Total area.	Remarks.
Cultivated.	Not cultivated for 3 years or more.	Total area.	Village site.	Railways and bank.	Canals.	Threshing floor.	Various.		

The register at this time was, therefore, a simple index to the maps, recording only the name of the proprietor, the area of the plot, and in general terms the purpose for which it was used. The rate of tax was not given, since there was said to be much difficulty in ascertaining the tax which was levied on each plot since the registers of the revenue showed rather the total due from each taxpayer, and not the details of which it was composed. In order to obtain from these cadastral registers the total area owned by any one proprietor, it was necessary to abstract the plots belonging to him from the record of each "hod" in which they occurred and to add them together.

In 1883 a great improvement was introduced by compiling a list or index of properties as well as the index of holdings. In this, all the pieces of land belonging to a single proprietor were grouped under his name, together with all details of area, quality ("ushuri" or "kharagi"), the "hod" in which each plot is situated, and the total amount of the tax paid by him, but the rate of tax levied on each plot could not be included, since the taxation lists only gave the rate of tax due from a certain category of land, and the revision of these lists involved a general re-assessment of the land-tax which was not carried out until sixteen years later. In this manner the land owned by each individual could be readily seen. The results were summarized at the end of the register, and the total area of land of different classes, *e.g.*, kharagi, ushuri, State property, and the special lands known as the State Domains and the Daira Sania lands were shown for each village.

The cadastral maps of the greater part of the three provinces of Gharbia, Qaliubia and Fayum were now completed, so that it was possible to combine them in order to form a map suitable for administrative purposes, and which would contain more detail than those which had been published under the direction of Mahmud Pasha el Falaki in 1872.* Maps of the district of Sammanud in the province of Gharbia, and Mehallet Menuf were lithographed in 1883 and distributed to the different administrations (see Plan XIX).

The extreme subdivision of the land in Egypt renders the number of plots which have to be shown on a cadastral map very large, and

* See page 74.

consequently much topographical detail has to be shown conventionally or even suppressed in order that the property boundaries may be visible. Palm groves if fully shown, and the slopes of the canal and river-banks if shaded, would make it difficult to see the small holdings which occupy the same ground. Consequently a small-scale topographical map produced by reducing the cadastral map alone, and by omitting property boundaries which do not correspond to topographical features, is very deficient in topographical detail, and this was the case with the district maps of 1883. The difference between such a map and one of the same part of the country which has been revised topographically on the basis of the cadastral maps may be seen by comparing Plans V and XIX.

In 1884 the sum which could be allotted to the Cadastre was only L.E. 28,533, but the staff was not reduced, a few even being added:—

Year.	Inspector-General.	Inspectors.	Sub-Inspectors.	Surveyors.	Assistant Surveyors.	Employees.	Chainmen.	Total.
1883	—	3	1	48	75	42	256	425
1884	1	2	3	53	68	39	276	442
Difference... ...	+ 1	− 1	+ 2	+ 5	− 7	− 3	+ 20	+ 17

Work was carried on in the provinces of Fayum, Qaliubia, Menufia and Gharbia, and a large area was surveyed, the details of which are shown in the following table, where the areas are given in feddans:—

Province.	Triangulated.	Surveyed.	Calculated.*
Fayum	19,500	15,763	27,301
Qaliubia	55,108	11,141	26,140
Menufia	69,400	33,364	5,038
Gharbia	91,127	97,587	19,806
Total... ...	235,135	187,858	108,585

* Areas of holdings being also calculated.

† Having been surveyed in the previous year.

In this year the practice was commenced of allotting special work to the Cadastre which, although not strictly cadastral surveying, was certainly such as required trained surveyors to carry it out satisfactorily. Such special work included the measurement of islands and Nile banks after the annual flood, in order to determine where old land had been eroded, and where new land had been deposited by the river ; surveying land which had not been irrigated and therefore could not be cultivated, so that it had to be relieved of tax for the year ; measuring the areas cultivated with tobacco and tombac ; moreover, a section of the Department of Indirect Taxes dealing with the renting and sale of Government land was transferred to the Cadastre.

In the report on the survey work for this year the Director complains of the grudging assistance rendered by the sheikhs of villages. He further reports that considerable difference was found between the areas of properties owned and the areas on which taxes were paid according to the land-registers. There was also much land owned which had not been previously inscribed, so that in the district of Sammanud an excess of 868 feddans of untaxed land was found. The practice of recording a landowner's property in a single village register although part of the land was situated at a distance and intermixed with the lands of other villages, was extremely common, but definite transfers of the land so included in the lands of another village do not seem to have been made in order to put an end to this confusing state of things which was not altered until the present survey.

The maps of the districts of Kafr el Zayat and Talkha in Gharbia province were compiled on the scale of 1 : 40,000 from the cadastral map-sheets and were lithographed and published in this year.

In 1885 the work of the staff of the Cadastre was divided between the regular cadastral survey and the special work. The technical staff numbered a hundred and ninety-five besides the necessary chainmen, etc., and was divided into two classes in the Central Administration, but the field parties were not definitely divided. There were now not only State lands to be surveyed, but also the annual measurements of islands and the lower parts of the river banks had to be made ; the exceptionally low Nile flood of 1884 had left much of the higher land unwatered, so that all such lands had to be measured in order that the land-tax might be remitted. Thus the special work was becoming larger each year and occupied the time of a considerable proportion of the cadastral staff.

The sum allotted to the Cadastre this year was L.E. 29,000, and the amount of work in feddans was :—

Province.	Triangulated.	Surveyed and calculated.	Calculated. †
Fayum	40,072	41,753	—
Qaliubia	29,735	—	59,110
Gharbia	117,589	71,053	—
Beheira	64,000	—	—
Menufia	—	1,008	6,680
Total ...	251,396	113,814	65,790

Besides this, 417,417 feddans of lands of different kinds such as sharaqi, tawalif, island-land, etc., in various parts of Egypt were dealt with, but this did not entail surveys in course of which maps had to be produced, though the area of each portion of such land owned by each taxpayer had to be determined and recorded.

Maps of the districts of Tala and Qaliub were lithographed on the scale of 1 : 40,000, and published in this year.

In March, 1886, Mason Bey was appointed Director-General of the Cadastre in place of Mr. Gibson, who had been nominated British Commissioner of the State Domains in April, 1885. The staff was increased by ninety-five employees for carrying out the measurement of lands in the different categories of special work, mainly in Upper Egypt, so that the total number employed amounted to over seven hundred, four hundred and fifty of these being technical employees :—

Year.	Inspector-General.	Inspectors.	Sub-Inspectors.	Draughtsmen and Clerks.	Surveyors.	Land Measurers.	Chainmen and Measurers.	Total.
1885	1	2	3	58	141	157	256	618
1886	* 1	2	4	51	140	258	258	713

* Director-General.

† Having been surveyed previously.

The budgetary provision was L.E. 28,700 for the Cadastre, L.E. 3,700 for work connected with the State lands, and L.E. 1,568 for special measurements in Upper Egypt, but in consequence of the very large amount of special measurement which was required during the year and which finally amounted to 900,000 feddans, the out-turn of the Cadastre in 1886 showed no increase over that of the previous year:—

Province.	Triangulated.	Surveyed and calculated.
Fayum	26,700	21,915
Qaliubia	906	18,889
Giza	4,300	—
Gharbia	61,796	—
Menufia	3,400	57,752
Total... ...	97,102	98,556

On February 12, 1887, the Administration of the Cadastre was transferred from the Ministry of Finance to the Ministry of Public Works, with a budgetary provision for the year of L.E. 27,520, but the section of the service which had since 1884 been occupied with the location and measurement of State lands remained in the Ministry of Finance.

The amount of cadastral work in feddans which was carried out in 1887 in each province under survey was :—

Province.	Triangulation.	Surveyed and calculated.	Calculated.
Fayum	11,000	8,171	34,348
Qaliubia	7,120	4,942	42,037
Beheira	32,046	4,303	2,103
Gharbia	26,500	26,856	58,980
Total ...	76,666	44,272	137,468

In 1888 the sum of L.E. 28,000 was provided for the work of the Cadastre, but in the autumn it was decided to suppress this service altogether from January 1, 1889, and this was done by a decision of

the Council of Ministers dated November 25, 1888. The work done during the year was similar in character to that in 1887 but no larger amount was completed.

It will be sufficient to summarize in a statistical form the information concerning this service as it is given in the annual reports. As in all work of this nature, it is difficult to state precisely the actual amount of work done in any period since both at the beginning and at the end of any period there is always much work in hand which is in every stage from that which has been just begun to that which is almost finished; only when the amount of such work is very considerable can the amount in hand at the beginning and end of a year, for example, be taken as approximately balancing one another, since it is impossible to estimate accurately what proportion of the whole work each operation represents.

The reports of the different years differ greatly in their form, and the statistics were not given in the same form in each annual report so that it is difficult to compare the work from year to year. In 1886 and 1887 fairly complete tables of the total amount of the work done since the Cadastre was instituted up to the end of each of these years were given. From the latter of these the state of the survey at the time when the Cadastre was suppressed has been compiled, and, though it is probably not quite accurate, the errors must be small.

The total area surveyed in ten years was 1,142,286 feddans, which included six hundred and twenty-seven villages; sixty-two other villages cannot be included since their areas had not been computed, and in thirty-two of them the survey had not been completed. The area of completed survey can therefore hardly have exceeded 1,200,000 feddans.

As has been already mentioned a portion of the staff of the Cadastre was for the last four years, 1885–1888, employed on special measurements and other surveys, so that these employees were not available for cadastral work; the whole of the budgetary provision in these years was therefore not expended on the Cadastre proper, so that it is difficult to arrive at an accurate estimate of the average cost of the work per 100 feddans (42 hectares), or other unit.

However, we find from the annual reports that the sums allotted each year to the Cadastre and expended on the work were as follows :—

Years.	Allotted.	Expended.
	L.E.	L.E.
1879-80	79,000	79,379
1881	60,000	56,936
1882	60,000	57,452
1883	35,000	32,880
1884	28,533	25,923
1885	29,000	29,000
1886	28,700	28,700
1887	27,520	27,520
1888	28,000	28,000
Total	L.E. 375,753	L.E. 365,790

Where the annual reports do not state the exact sum expended, it has been assumed that the whole amount provided was utilized.

The state of the work at the time when the Cadastre was suppressed is given in the following table: thirty-five of the villages therein accounted for are incomplete, so that during the ten years that the

service had existed, six hundred and fifty-four villages had been surveyed; the distribution of the villages was as follows :—

Provinces.	Districts.	Total.	Remarks.
Fayum	Sennures	32	
	Medina.	44	
Qaliubia	Qaliub..	56	
	Shubra.	53	Now Dawahi Masr and Nawa.
	Tukh	1	
Gharbia... ...	Gafaria.	70	Now Santa and part of Quesna.
	Talkha..	55	
	Sammanud.. ...	66	Now Tanta.
	Kafr el Sheikh...	50	
	Kafr el Zayat ...	49	
	Zifta	58	
	Sherbin	28	
	Desuq...	5	
	Mahallet-Menuf.	47	
Menufia... ...	Tala	54	
	Melig...	16	Now Shibin el Kom.
	Ashmun	1	
Sharqia	Mina el Qamh ...	1	
Beheira	Damanhur... ...	1	
	Abu Hommos ...	2	
	Total	689	

The uncompleted villages were mostly in Gharbia province, and their distribution was :—

Province.	Villages surveyed.	Villages unsurveyed or incomplete.	Total.
Fayum	68	8	76
Qaliubia	103	7	110
Gharbia	409	19	428
Menufia	71	—	71
Sharqia	1	—	1
Beheira	2	1	3
Total...	654	35	689

So that after ten years' work, not a single province had been completed, and the one which was most advanced had only about nine-tenths of its area mapped. (See Plan XVII).

The report for the year 1888 was not published so the last statement of the work done from the commencement of the cadastre in 1878 is that in the report for the year 1887 which gives the total area surveyed up to the end of that year:—

TOTAL AREA SURVEYED FROM 1878 UP TO DECEMBER 31, 1887.

Inspections.	Provinces.	Districts.	Completed.			Surveyed.*			Under Survey.			Total.		
			Number of villages.	Feddans.	Plots.	Number of villages.	Feddans.	Plots.	Number of villages.	Feddans.	Plots.	Number of villages.	Feddans.	Plots.
I	Fayum	Medina	29	111,325	29,924	10	20,439	8,678	4	10,256	5,032	43	142,020	43,634
..	.. ..	Sennures	13	26,175	15,592	7	12,722	10,831	5	3,637	4,121	25	42,534	30,544
II	Qaliubia ...	Qaliub	56	74,774	24,232	—	—	—	—	—	—	56	74,774	24,232
..	.. ..	Shubra	42	43,674	20,683	—	—	—	2	1,480	407	44	45,154	21,090
..	.. ..	Tukh	1	2,064	1,030	—	—	—	—	—	—	1	2,064	1,030
III	Beheira ...	Abu Hommos ...	1	2,200	200	—	—	—	—	—	—	1	2,200	200
..	.. ..	Damanhur	1	2,103	217	—	—	—	—	—	—	1	2,103	217
..	Menufia ...	Tala	34	47,984	28,334	19	35,540	19,524	1	112	200	54	83,636	48,058
..	.. ..	Melig	—	—	—	11	10,391	8,837	—	—	—	11	10,391	8,837
..	Gharbia ...	Kafr el Sheik ...	33	68,823	7,437	4	3,850	1,184	1	17,500	1,200	38	90,173	9,821
..	.. ..	Gafaria	44	53,469	29,897	22	26,417	15,771	2	6,892	1,010	68	86,778	98,678
..	.. ..	Kafr-Zayat	47	61,127	22,370	—	—	—	1	6,342	1,347	48	67,469	23,717
..	.. ..	Mehallet-Menuf ...	46	84,145	34,417	—	—	—	—	—	—	46	84,145	31,417
..	.. ..	Zifta	31	28,338	18,590	1	350	300	13	10,252	6,149	45	38,940	25,039
..	.. ..	Dessuq	3	3,585	1,147	—	—	—	1	6,000	862	4	9,585	2,009
IV	.. ..	Samanud	62	121,723	23,424	—	—	—	—	—	—	62	121,723	23,424
..	.. ..	Talkha	43	89,775	14,243	11	17,816	4,698	—	—	—	54	107,591	18,941
..	.. ..	Sherbin	19	58,666	3,683	—	—	—	7	72,340	2,331	26	131,006	6,014
			505	879,950	275,420	85	127,525	60,823	37	134,811	22,659	627	1,142,286	367,902

* Areas being calculated.

We thus arrive at an expenditure of L.E. 365,790 for surveying 1,200,000 feddans, and triangulating in an elementary manner a somewhat larger area ; which corresponds to an average cost of L.E. 30·5 per 100 feddans. However, a considerable sum during the last four years was expended on other measuring work, and, if we assume this as equalling in cost one-half of the work in each year, about L.E. 56,000 should be deducted from the total cost of the cadastral work, which might reduce the average cost of triangulating, surveying and recording 100 feddans to rather more than L.E. 25, but all sums which are definitely stated in the reports to have been expended on work other than the Cadastral survey have been omitted in obtaining the former figure.

Since no province was completely surveyed the work does not seem to have been utilized to correct the areas of properties and thereby the amounts of land-tax to be collected. Maps and registers were stored away and no further use was made of them. The majority remained in the Ministry of Public Works, and these are now in the Map Store of the Survey Department; the rest were sent to the Ministry of Finance in 1888. Though now of no authority in questions of land-ownership these maps are not infrequently referred to in order to ascertain facts relating to the topography of the country twenty or thirty years ago. They furnish valid evidence of the existence or non-existence of buildings, canals, banks, etc., and are of use in this respect; since this information is topographical it is important to place on record the manner in which the measurements were made, that an estimate may be formed of their accuracy. To have initiated a good second order triangulation in 1878 would have postponed the preparation of village maps for a year or eighteen months, but this delay would have been rapidly made up afterwards, and the cost of such triangulation and a mathematical control would have soon been recovered by improved accuracy of work.

CHAPTER VIII.

The Hydrographical Survey of 1889–1898.

When the Cadastre had been suppressed there only remained the section of surveyors which had been transferred to the Ministry of Finance two years before in order to deal with matters relating to the sale and letting of State lands. But at this time the reorganization of the irrigation was advancing rapidly and considerable works were about to be undertaken in Upper Egypt in order to safeguard that part of the country against the want which was caused by exceptionally low floods, of which that of 1888 had just furnished an example. In the Delta, the Barrage near Cairo was being repaired and made fit for use, supply canals and drainage channels were being dug, and works for regulating the volume of water to be furnished to each part of the canal system were in course of construction. Reliable maps were urgently required in this work and very few were available. In Upper Egypt there were only those prepared under the direction of Mahmud Bey (see p. 74) which had never been printed, and in the Delta there was his map on the scale of 1 : 200,000 and those of Gharbia, Menufia and Qaliubia provinces and a part of Beheira province as well as such maps of districts as the late Cadastre had published on the scale of 1: 40,000. Only four of these maps had been published, and on them very little topographical detail appeared ; the cadastral maps of the greater portion of three provinces existed, but they were on too large a scale for engineering purposes and moreover they had never been printed. A considerable amount of surveying and levelling had already been done in connection with the execution of irrigation works during the past seven years, and great efforts had been made to supply maps showing the existing topography of the country by utilizing whatever existed as a result of the somewhat spasmodic efforts which had been made during the century to prepare a map of Egypt.

None of these maps showed any property boundaries, nor did the revisions of them, which were prepared for the use of the irrigation engineers by the hydrographical survey, supply anything more than a topographical plan of each province, but the triangulation which

was employed in the province of Giza was used in 1898 to control the chain survey of the new Cadastre, so that it is desirable briefly to place on record the methods resorted to and the results obtained.* The Cadastre of 1878-1888 restricted its operations, as we have seen, to four provinces in the Delta and that of the Fayum in Upper Egypt, so that the engineers of the Irrigation Service had been obliged to prepare such maps as were necessary for their work in the Nile Valley. They therefore took the existing maps which had been made in 1870 and 1871 (see p. 74) on the scale of 1 : 25,000 and corrected them roughly, but without undertaking a full revision in the field, for which there was no time to be spared from other urgent duties. These corrected copies were reduced to the scale of 1 : 100,000 and were reproduced by lithography in colours, black being used for place-names, railways, etc., blue for water, red for towns and villages, green for the cultivable land, and brown for hills and the desert.

Neither in 1870 nor during the revision of these maps in 1885-1886 had any attempt been made to show the cliffs of the Nile Valley in their exact position with accuracy, so that this portion of the country was represented on the maps in a purely conventional manner; the topography of the desert was completely omitted.

In the Fayum a certain amount of re-survey and revision was done during the reorganization of the irrigation system in this province, but in the main the maps of the Irrigation Service were based on those made originally under Mahmud Pasha el Falaki with such corrections and additions as could be made without undertaking a complete revision of them. This applied to those of the province of Giza and all the provinces to the south of it.

In the Delta, where perennial irrigation had been long in operation, the task of supplying water to the crops throughout the year was more complicated than that of filling and emptying the basins of the valley, and topographical maps were an urgent necessity. On the abolition of the cadastral survey, therefore, the Ministry of Public Works found it necessary to maintain a small staff in order to prepare a hydrographic map of Lower Egypt for the use of the Irrigation

* Some of that which had been done in Gharbia province was used to control the theodolite traverses there in 1896-97, but owing to the position of the triangulation points being uncertain the use of it was discontinued.

Service and to carry out the levelling and surveying needed in designing the improvements and modifications which were being introduced into the system of distributing the water of the Nile. Beheira was the first province in which work was commenced, and in 1889 a series of small triangles were observed which were to form the basis of a topographical survey carried out by means of the plane-table. In the provinces where the cadastral survey had worked traverses were carried along the railways in order to connect the several groups of triangulation which had been observed in the years preceding 1888.

The methods used were essentially those of the old Cadastre, on which most of the surveyors had served, and as the field maps were prepared on the scale of 1 : 10,000 there was no particular inducement to improve the accuracy of the system, since it was assumed that whatever had been used for the survey on the scale of 1 : 4,000 would be amply good enough for maps on the scale of 1 : 10,000 ; moreover, the funds available were very limited and the maps were required as soon as they could possibly be produced. A short base-line of about 2,000 or 3,000 metres in length was measured in each province by means of a 20-metre steel band, which was assumed to be of correct length, and no correction was applied either to reduce the length to any definite temperature, or to allow for any changes of temperature which might have occurred during the measurement. The sides of the triangles were about three kilometres long, and all three angles should have been observed, but it is evident from the angle-books that this was often evaded, and that the third angle was obtained by deducting the sum of the two observed angles from 180°. The angles in Giza province were measured with an 8-inch theodolite furnished with three verniers. Each angle was observed both "face-right" and "face-left," but not on different parts of the circle by taking several "arcs." The computation of the triangles and of the co-ordinates was carried out in the field by the observers themselves, who employed magnetic azimuths, so that the accuracy of the result was only such as would suffice for small-scale maps. At first the triangulation points were marked by wooden pickets, which were soon removed or lost, and in Beheira and Daqahlia provinces no other marks were employed. In 1895, while Sharqia province was being surveyed, iron marks were introduced, and these were also used in the part of Gharbia which was triangulated in 1896 and 1897. An attempt was made to utilize this

triangulation in 1897, but much caution had to be exercised, for the points were first marked with wooden pickets and from these the observations were made; afterwards a chainman replaced the wooden picket by an iron mark, but he did not always realize the necessity of doing so with considerable precision, so that the iron marks are not infrequently as much as two metres out of place. The co-ordinates of the triangulation were computed with the aid of the magnetic azimuths and the positions so obtained were plotted on the scale of 1 : 10,000 on field-sheets. On these the topographical detail was plotted by means of the plane-table by intersecting graphically a number of points and drawing in the detail with the aid of a few measured offsets. Even with this simple procedure the maps so made were a very great advance on any which had been produced previously and were of the utmost value to the Irrigation Service. Unfortunately the Drawing Office of the Ministry was not able to reproduce these maps on this scale, viz., 1 : 10,000, since it was too large a piece of work for the staff which then existed, so reductions to 1 : 25,000, 1 : 50,000 and 1 : 100,000 were prepared, but only the last of these was lithographed and published in two editions, English and Arabic.

Maps of Lower Egypt, scale 1: 100,000.

Province.	Triangulated.	Surveyed.	Published.
Beheira	1889-93	1889-93	1895
Gharbia	1890-91, 1894-98	1890-91, 1894-98	not completed
Daqahlia	1891-95	1891-95	1896
Sharqia	1893-96	1893-96	1897

This survey was primarily topographical and will therefore be more fully described in the report on that branch of the work of the Department. *

* Lyons. "Topographical Surveying in Egypt." (in the press).

CHAPTER IX.

State Lands Survey, 1891–1896.

The reorganization of the system of irrigation in Egypt, which was commenced by Sir Colin Scott-Moncrieff in 1883 and which was carried on systematically year by year throughout the country, soon began to show results. Canals which had become silted up were cleared, others were straightened and remodelled, a more methodical system of distribution was introduced, drains were dug to carry off the water from water-logged lands and to remove that which was used for washing salty ground. By 1891 much had been done and order had taken the place of the chaos which had reigned over wide areas of the country as late as ten and fifteen years before. Channels of more suitable size and slope and more correctly laid out were now carrying the silt-laden water of the flood to areas which had long been deprived of it, and by more systematic arrangements for distribution land which had hitherto been out of reach of a good water-supply was now regularly irrigated. This general improvement in the distribution of water was followed by a rapid development of cultivation; cultivated areas which had hitherto been separated by tracts of poor or waste land extended their limits by reclaiming portions of these and gradually, as the supply of water became regular and assured, a large amount of inferior land was improved and brought under cultivation. Along the margin of the Delta where the cultivation and the desert joined there were large tracts of low-lying land which were only reclaimable if a regular water-supply was available and if the surplus water could be drained off. Here, too, there lay large tracts of the lands collectively termed "Kharig el Zimam" or land which had been considered as outside the province of earlier cadastral records since it was uncultivated and, under the conditions then existing, uncultivable. Although some of this land had been in the past granted to individuals on the condition that it was reclaimed,* much of it still belonged to the Government, but often, in the absence of maps on which these areas had been

* See Chapter V, p. 67.

shown, its location was a matter of much difficulty if not absolutely impossible.

Nowhere had the improvements in the irrigation been greater than in the district of El Arin (now Faqus) in the province of Sharqia, and here large areas of land which had hitherto been unproductive were year by year being brought under cultivation. The revenue returns, however, did not show any marked increase of land under cultivation, and in the early part of 1891 an enquiry was instituted in the village of El Menaga near Salhia to investigate the matter and to verify the area which was actually being cultivated. This village was situated on the margin of the desert and near the end of the Sarana canal. Much had been done to improve this and the neighbouring canals as well as the large Bahr el Baqar drain so that a considerable increase of cultivation was to be anticipated in the area which they served.

It was then found that much land was under cultivation which was not entered in the land-register of the village, since the landowners had in many cases encroached on the Government land lying within and near the village boundaries. In the autumn of 1891 therefore a re-measurement of the lands of this village was made to ascertain the extent of these encroachments and resulted in the total cultivated area which should have been recorded in the land-register being increased from about 2,000 feddans to about 5,000; this village has since increased its area of cultivated land to 12,566 feddans. The excess thus found was sold at very moderate rates to the inhabitants and the neighbouring proprietors, the purchasers being mostly Bedawin. These results showed the necessity for such measurements as would ensure that the land which was being brought under cultivation in consequence of the improved system of irrigation, was duly recorded, and at the same time would guard against unauthorized encroachments. In 1892, therefore, the sum of L E. 6,000 was provided for surveying a few villages in Sharqia province as an experiment, in order to ascertain the amount of Government land which was cultivated without title by the inhabitants, and on which, for the most part, neither rent nor tax was being paid. This work was the commencement of the present cadastral survey. The sum allotted was to cover not only the cost of surveying the land but also all further expenditure incurred in disposing of the land to those who were cultivating it or who wished to purchase

it; the actual amount expended in the field survey in 1892 was L.E. 3,500.

At first, in 1892, nine engineers and twelve surveyors were employed under an inspector; several of them had previously been assistant engineers in the Cadastre of 1878–1888 which had been suppressed three years before, so that naturally the same technical methods were employed. There was no question at this time of making a complete survey of the whole country, but only of re-measuring the State lands in the villages in order to check the wholesale encroachment upon them which was everywhere in progress as a result of the reorganization of the irrigation. For the moment, also, the work was merely experimental and therefore the survey of individual villages only, and not of a large tract of country, was contemplated, so that no systematic triangulation was carried out. The "hods" into which each village was divided were surveyed by means of graphic triangulation executed with a plane-table, just as had been done in the earlier cadastral work (see p. 86), and short base-lines were measured with a chain. These were plotted on the field-sheets on the scale of 1 : 4,000 and from them numerous points were fixed by intersection, from which the boundaries of the "hods" could be drawn in. Other important features, such as canals, public works, large areas of State lands, and properties of over twenty feddans in area, were also mapped in this way. The question of plotting the smaller holdings was considered and an experiment was made in the village of Awlad Musa, but it was decided that for the time being private holdings smaller than twenty feddans in area need not be shown on the maps on account of the additional time and expense involved.

The smaller holdings were measured by the surveyors with qassaba rods or five-qassaba chains, and their areas were computed according to the old Egyptian rules, the results being compared with those obtained from the area of the larger portions of which they formed part and which were calculated from the maps by the ordinary methods of mensuration, and with the planimeter. This work was not plotted to scale on the maps but the computed area of each holding was recorded in a register.

In this respect there was a distinct falling below the standard of the work of the older Cadastre, but this was to be excused on the grounds that the object was to locate the State lands and not to establish a

survey and register of property ; besides, Sharqia was not one of the provinces in which the Cadastre of 1878-1888 had been carried out, so that the old records of Bahgat Pasha's measurements made forty years before were all that were available. These were again followed as a pattern and in them the name of each landowner was written, with the dimensions of his plots in qassabas beneath ; the computation and the results were given, as already explained in Chapter VI (p. 71). Printed registers were not introduced until 1896.

The sub-inspectors checked the work by chaining check-lines and by intersections obtained with the plane-table ; some of the holdings also were re-measured by them and the areas thus determined were compared with those obtained by the surveyors ; the areas of the larger divisions which the engineers had mapped and computed were also checked by the sub-inspectors with the planimeter.

By the means of even these simple methods, large areas of Government property were found which were being illegally cultivated without either rent or tax being paid ; when these encroachments had been located much of this land was sold by auction or by private treaty at a moderate price to those who were already cultivating it, with the object of settling them on the land. They thus obtained a title to the land they cultivated, and fully appreciated the benefit of this arrangement.

At first there was considerable variety in the methods employed, for some of the surveyors included a large amount of detail, while others mapped little more than the hod boundaries and the principal features. This diversity was gradually eliminated, and before long all the work was carried out systematically on the plan described above.

So far from any opposition being raised to this survey, the general attitude of the inhabitants was surprisingly favourable ; it was certain that a large amount of Government land would be found to be included in private holdings or to be clandestinely cultivated, and on this they would be compelled to pay taxes. Still the belief that the Government would be willing to sell them this land at a reasonable price, and so relieve them from frequent partial re-measurements, claims, and disputes, inclined them to welcome a definite settlement of the matter.

This development of irrigation on the margin between cultivation and desert gave a great impulse to the development of the agriculturist from the nomad in bringing waste land under cultivation. Much of this

newly reclaimed land was bought by Bedawin who eagerly seized the opportunity of eking out their meagre existence as horse and camel owners by cultivating barley, beans, bersim, ground nuts, and in some cases even cotton. Without giving up their ancient occupation they found that adopting in part an agricultural life increased their comfort and prosperity, while from the point of view of the State they became more orderly and more readily controlled.

Besides the village of El Menaga which was begun experimentally in 1891, eleven others in the same district were commenced in 1892; they have again been surveyed recently in order to publish maps of their holdings of the same standard of accuracy as has been attained in other provinces which have been surveyed since 1898; their areas as determined at these two periods may therefore be compared although some of the difference is due to the reclamation of waste land which was not included in the earlier survey:—

AREA IN FEDDANS.

Village.	1892.	1907.
	Feddans.	Feddans.
Dawar Gaheina	1,609	1,547
Kafr el Hag Omar	1,393	1,380
Sawada	4,276	4,442
Deideimun	4,470	4,417
Awlad Musa	3,750	3,755
Dawamir	8.013	7,911
El Akheiwa	15,835	16,357
Qahbuna...	8,499	8,650
Akiad	9,932	10,038
Salhia	17,149	17,130
Qantir	2,642	2,627

The value of the survey, even on the modest lines hitherto followed, was by this time so well demonstrated that in 1893 the sum of L.E. 12,500 was allotted to the work, which enabled four other districts of Sharqia, namely, Belbeis, Miniet el Qamh, Ibrahimia (now Kafr Saqr), and Sawala (now Hehia), to be taken in hand in addition to the one already under survey. In each district a sub-inspector was in charge of the work, with seven engineers and eight or nine surveyors under him; work was also commenced in Beheira province under an inspector during the same year.

The total staff employed in this year was :—

	Sharqia.	Beheira.
Inspectors	1	1
Sub-inspectors	8	1
Engineers	28	16
Surveyors	28	16
Chainmen	120	70
Total...	185	104

In 1893 with the sum of L.E. 12,500 which had been provided the survey of the State lands was carried out on the same lines as in 1892; the lands of each village were measured, the area registered in the name of each landowner was located, and when encroachments on Government property in excess of five per cent. of the area owned were discovered, the settlement of the existing occupier on the land was attained by transferring to him the land in return for a payment which represented a moderate compensation to the Government for the loss of taxes to which it was legitimately entitled, rather than the market value of the land. The maps were coloured to show the State lands and the divisions of the village, but private property was only partially indicated. (See Plan XVIII).

Work was continued on these methods throughout this year, and also the next in which a larger grant was made, L.E. 18,206 being expended on surveying work in Beheira and Sharqia provinces.

The end of 1895 marks a definite stage in the development of the survey of Egypt. The work of the past four years had definitely shown that large areas of Government land had been encroached upon or appropriated, without the fact being known to the authorities on account of the form in which the land-registers were kept and the procedure which was followed for their correction and verification. Moreover, the measurements recorded in the village registers were often very inaccurate, and in most cases only the total area owned by each proprietor was recorded, although more often than not such properties consisted of numerous small plots which were situated in different parts of the village lands. In such cases the register furnished no means of identifying on the ground the different plots of which a

property was composed, so that it furnished but little assistance in elucidating claims of possession or complaints of encroachment.

In the four years 1892–1895 much had been done in two provinces to improve this state of affairs, and incidentally about L.E. 128,000 had been collected on account of 42,350 feddans which had been sold to those who had been found in illegal occupation of them by means of the surveying operations on which some L.E. 56,000 had been expended. The survey was now to enter upon a wider sphere of action, since it had become necessary to carry out a re-assessment of the land-tax throughout the country, where in many cases poor land was paying a higher tax than neighbouring land of good quality, a relic of the fiscal disorganization of the preceding decades.

A Commission under Sir William Willcocks was appointed in 1895 to examine into the incidence of the land-tax as it then existed. A notice was issued by the Government that the total amount of land-tax would not be increased but that the land-tax would be re-distributed in order that it should bear a relation to the value and fertility of the land, thereby putting an end to numerous anomalies which existed. In no case was the existing maximum rate of tax of L.E. 1.640 per feddan to be exceeded.

This work of re-assessing the rates of land-tax was carried out by ten sub-commissions each of which consisted of two official members, one being an European, and two non-official members who were selected by the Mudirs from a number of landed proprietors elected by representative landed proprietors. *

These sub-commissions visited each village and assessed the rate of tax that the land in each "hod" of the village should bear according to its quality, in order to arrive at the total amount of tax that the village should be called upon to pay. The work was completed throughout the whole of Egypt in fifteen months, and the total amount of the land-tax to be paid by each village was indicated in a report. There were several reasons why these results could only represent the first stage in the scheme of re-assessment: firstly, there were no maps on which the boundaries of the "hods" were shown, so that their limits were only approximately ascertainable; secondly, the areas of both "hods" and villages were only known with a very moderate degree of accuracy; and thirdly, if the rate of tax was fixed for any

* Communicated by Mr. H. A. Humphreys.

"hod" or the total sum to be collected from any village was determined there was much to be done before it could be apportioned among the individual proprietors. Since in the village land-registers the land belonging to each taxpayer was shown as a single total, or sometimes as two or three amounts with meagre indications of the part of the village in which the lands lay, it was not possible to determine what rate of tax was due from properties made up of several small plots which for the most part were not contiguous or even adjacent, but were separated by some distance, and were often in different divisions of the village, being probably of different degrees of fertility.

The area subject to each rate of tax was shown separately and the total amount of the tax which the owner had to pay was thus arrived at; but when the tax was re-assessed it might happen that some of his land at a high rate of tax might have to be transferred to a lower rate or vice versa, so that it became essential to locate each separate holding on the ground and to plot it to scale on a map so that holdings of which the rate of tax was changed could be separated from those on which it was maintained. This necessitated a considerable change in the survey methods and the addition of a large amount of detail to the village maps which had hitherto shown no private property of less than twenty feddans in area, and this amounted to re-measuring all the cultivable land in Egypt and re-writing all the land-registers. A more effective control of the chain survey than the graphic triangulation which was carried out by means of plane-tables and telescopic alidades had to be introduced, and the computation of field areas could no longer be derived from the measurements by the old Coptic rules of arithmetic which have already been discussed (p. 43).

In 1895 the engineers had begun to measure and plot in detail all holdings of ten feddans and upwards, and the surveyors were being instructed to plot their measurements to scale; areas of each "hod" were at this time calculated twice, once from the measurements taken in the field and a second time by means of a planimeter from the map after the work had been plotted. The surveyors' areas computed from their field measurements were compared with these "hod" areas and differences which exceeded 1·0 per cent. were enquired into.

At the end of the year theodolite traverse was introduced to control the detail survey; surveyors commenced to plot their measurements to scale, and all holdings except the smallest were shown on the maps;

areas of villages were computed from observations made in the course of the traverse and the areas of fields were obtained with the aid of the "feddan comb";* the measurements were all made in metres and plotted to the scale of 1 : 4,000 while the final areas were taken out in feddans. At this point then we enter upon the second stage of the Revenue Survey when it developed from being primarily a survey of State lands made with the object of locating Government property and checking encroachment, and became to all intents and purposes a cadastral survey. The changes which were afterwards made from time to time aimed at expediting and facilitating inspection and control, but the scope of the survey did not greatly alter.

The total area which had been surveyed by the earlier methods between the beginning of 1892 and the end of November 1895 was reported as amounting to about 478,000 feddans completed, and another 1,277,000 feddans in various stages, which were distributed as follows :—

Province.	Completed.	Awaiting approval.	Surveyed by engineers and surveyors.	Surveyed by engineers.	Not commenced.	Total area of province.†
Sharqia	159,000	145,500	247,000	410,000	—	818,417
Beheira	174,000	—	212,000	408,000	293,000	1,087,001

The sum expended on this work in these four years was as follows:—

Year.	Sum expended on survey.
	L. E.
1892	3,500
1893	12,500
1894	18,206
1895	21,872
1892–5...	56,078

The above areas are but estimates and, in the case of Sharqia, they are liberal ones, for although the province was not yet completed, the

* For a description of this see Chapter XV.

† By final measurement.

area returned amounts to 150,000 feddans more than the total area of the province. Omitting the areas surveyed by the engineers only, as being in the first stage of the work, the area surveyed in four years amounted to 937,000 feddans up to the end of November 1895, which had been surveyed at a total cost of L.E. 56,078 or we may consider about 1,000,000 feddans as having been completed for this sum by the end of the year; this gives a rate of fifty-six milliemes per feddan which would perhaps become fifty milliemes per feddan if the land surveyed by the engineers were allowed for, but might rise to sixty if the over-estimated areas could be corrected (cf. cost given on p. 143). Sales of land as the result of this survey of the State lands had realised L.E. 128,000 and the yearly receipts from the land-tax had been increased by about L.E. 7,000.

As the Re-assessment Commission was already at work, the question of the modifications to be introduced into the State Lands Survey was already engaging attention. Mr. B. Fuller,* who was at this time in Egypt for the purpose of advising upon the development of agriculture in the country, was also asked to give his opinion on the survey and to suggest any improvements which he might consider desirable. In reporting on the work of the survey he pointed out that the rate of work must be increased if the land-tax was to be re-assessed within any reasonable period of time, and that an independent control should be introduced to restrict the errors of the chain survey; he also considered the cost to be high when compared with that of similar work in India. With the view of expediting the survey and improving the control the work was divided into two parts of which the first was executed by a Technical branch who carried out the survey and the field-measurements, plotted these to form maps, and prepared a comprehensive index to the map of each village in which each plot was entered together with its area, the class of land, the rate of tax, the name of its owner, and of the present occupier. The second part was entrusted to a Settlement branch who received the map and the index (land-register) and from them prepared a statement of each landowner's total property and the total tax payable by him; errors and complaints were investigated and State lands were leased, sold or otherwise dealt with. In order to control the chain survey

* Now Sir Bamfylde Fuller.

closed traverses were to be introduced with such subsidiary traverse lines as might be necessary, and the points on these lines furnished a series from which the detail measurement could start and on which it could close ; being computed in the central offices from the traversers' field observations, their accuracy could be better controlled than that of the graphic plane-table triangulation which had been employed hitherto.

The first polygonal traverse was made in September 1895, when the area of some 20,000 feddans of land, known as Shiflik el Wadi, in the Wadi Tumilat between Zagazig and Ismailia, had to be determined in a few days. In the winter of 1895-1896 some villages in the province of Sharqia were traversed, the details being filled in by surveyors who had had a brief training in this new class of work. These villages were isolated ones, or were situated in groups of two or three, being surrounded by other villages which had previously been surveyed with the plane-table and graphic triangulation ; magnetic meridians were employed. At first small angle-measuring instruments—goniometers—were employed which had a horizontal circle of only six centimetres in diameter and could be read to 2′ by means of a single vernier. The staff were not sufficiently expert to obtain satisfactory results from these instruments, of which the telescopes were not powerful enough for the length of the line over which they were used ; they were introduced at first from motives of economy, but were soon replaced by 5-inch vernier theodolites.

Work had been commenced in Gharbia towards the end of 1895 and in this province all the villages were traversed.

To assist in introducing these new methods of survey and to organize the Technical branch as quickly as possible the services of an officer of the Indian Revenue Survey were obtained and he took charge of this branch from April 1896 until October 1897, when he returned to India.

This year, 1896, was therefore one of transition from the older method of survey with the plane-table to the new methods of closed traverse circuits within which the detail was measured and plotted to form a complete map of the village on the scale of 1 : 4,000. The change took some time to effect and it was not until the end of the year that the new system was in full working order. The principal reason for this was that in order to use the maps which had been prepared on the old system for re-assessment of the land-tax it was necessary to show on

them the private holdings, which in most cases had not originally been done ; this work occupied three inspectors and a considerable proportion of the staff during the latter part of 1895 and for a large part of the next year, but at the same time it allowed the traverse work to be observed and computed in time for use by the detail surveyors.

In this year the technical staff was divided into three sections, which were employed in :—*

(1) Completing villages already surveyed under the old system ;
(2) Making sketches to show the position of the plots in each hod of these surveyed villages for the use of the Re-assessment Commissions ;
(3) Being instructed in the new methods of traversing and plotting on maps.

Each traverse party consisted of an engineer and four chainmen who were equipped with a vernier theodolite and two chains of unequal length. The angle at each change of direction was measured with the theodolite (without change of face) and the distance was chained with each chain ; the results were computed in the central office on Gale's method with the aid of Boileau's traverse tables, the calculations being checked by using Fuller's (spiral) slide-rule. The permissible error was fixed at one per thousand in length but the amount of that in direction was left to the chief computer's discretion and no limit was laid down. Isolated villages or small groups of villages which were surrounded by others already surveyed by the old methods were traversed first of all, and magnetic azimuths were employed just as had been done for the plane-table triangulation. When new districts were commenced the azimuths were determined by observations taken on the sun, when near the horizon, with a theodolite, the altitude and direction being read off simultaneously on the vertical and horizontal circles ; these observations were taken at points where the boundaries of three districts joined and at intervals of about fifteen kilometres along these boundaries.

In the computing office these azimuths were calculated and the traverse angles between each azimuth point were corrected until they fitted in with the observed azimuths which were assumed to be free

* This account is compiled from information furnished by Mr. Villiers Stuart.

from error. The thirty-first meridian east of Greenwich was taken as the central meridian of the area for the purpose of projecting the maps and computing the co-ordinates of points, but as no map was prepared to include a larger area than the lands of a single village this was not specially made use of; map-sheets having continuous sheet-lines were not introduced until some years later when the triangulation of Qaliubia and Daqahlia had been completed. As soon as each district had been completely traversed a sketch was made showing the boundary, and all the interior circuits, as well as the closing error of each circuit, after the necessary correction had been applied to the main circuit. The angles common to the main and interior circuits having received the same correction, the sum of the + errors was equal to the sum of the — errors in the interior circuits. The errors of the interior circuits were then so distributed that the + and — errors neutralized each other and the whole angular work became consistent, in that no line could have two bearings attributed to it.

In 1896 work was carried on under the new system in the provinces of Sharqia, Beheira and Gharbia. A sum of L.E. 25,000 was allotted to the work and the staff authorized consisted of:—

1 chief inspector,
6 sub-inspectors,
49 engineers,
190 surveyors,
505 chainmen.

Of this staff, 1 inspector and 9 engineers were to be employed upon theodolite traverse work, while the remainder would continue the chain survey, being divided into five inspectorates each consisting of:—

1 sub-inspector,
8 engineers,
38 surveyors,
100 chainmen.

At the end of 1896 the actual number of engineers and surveyors was 177.

Training the staff in new methods, and inserting the holdings on maps where they had not been plotted in villages surveyed under the old system, took up much time, so that only 55,199 feddans of new work were surveyed during the year; but the traverse work advanced rapidly and furnished the points necessary for controlling the chain survey.

In reporting on the work of this year, 1896, Mr. Dunne, the Chief Inspector in charge of the Technical branch, speaks of the difficulties which were met with in marking the traverse points in the field; at first, wooden pickets were used, but these were continually removed; then pottery cylinders about 15 centimetres in diameter and 45 centimetres in length were tried, but these proved even more attractive to the fellahin, being admirably adapted for the construction of the small watercourses which are used in the irrigation of the fields, and they were removed almost as fast as they were put down. Wooden pegs were therefore again employed for a while, and were then superseded by roughly dressed limestone blocks about 0·20 × 0·20 × 0·50 metre in size. During the year, 601,529 feddans were traversed, comprising 483 villages, by a staff of seven traverse engineers; such details as are now obtainable of the cost of the work, the average number of points per square kilometre and the average length of line are given in chapter XIV. Considerable difficulty was experienced at first in training the surveyors to work from the traverse points and use them to control the chain measurement; they had been so long accustomed to use the old method of measuring each plot separately that they almost unconsciously reverted to their usual system, but by forming a class of instruction through which all were passed, the new method was successfully introduced during the year.

Printed forms were now prepared which replaced the old manuscript registers, and columns were provided for the different items of information which were recorded concerning each plot.

The amount of work done during the year is shown in the following table :—*

TRAVERSE WORK EXECUTED DURING 1896.

Provinces.	No. of villages traversed.	Total area traversed.	No. of azimuths observed.	Average distance of azimuth points.	No. of villages plotted.
		Feddans.		Kilos.	
Sharqia ...	137	142,072	0	—	137
Beheira ...	238	304,947	15	22	180
Gharbia ...	108	154,510	3	18	0
	483	601,529	18	40	317

* Taken from the Report on the Technical Branch for 1896.

The Staff which was employed from April to December consisted on the average of:—

Control.		Supervision.	Survey.		Office.	
Inspector.	Sub-Inspectors.	Engineers.	Traversers.	Messahin.	Draftsmen and Computors.	Clerks.
1	5	24 *	7	130 *	14	4

The work consisted in adding information to the work previously done so that it could be used for the re-assessment, and in carrying out a chain-survey in connection with the new traverses which would be a Revenue Survey instead of one of State lands only.

Area Surveyed during 1896.

Provinces.	Estimated area of Mudiria †	Boundary Survey.		Field Survey.			Average number of surveyors during year.	No. of villages for which maps prepared.
		By plane-table surveyed in previous years.	By traverse surveyed during 1896.	Total area surveyed.	No. of fields surveyed.	Average size of each field.		
	feddans	feddans	feddans	feddans		feds.		
Sharqia ...	532,418	390,346	142,072	57,684	37,391	2·9	53	76
Beheira ...	482,372	177.424	304,947	76,666	17,560	4·4		40
Gharbia ...	968,235	—	154,510	—	—	—	—	—
	1,983,025	567,770	601,529	134,350	54,951			116

* Besides 4 engineers and 15 surveyors engaged in completing old work in Sharqia province.

† These figures are given in the report quoted, but they do not represent the whole area of the province, as may be seen by comparing them with the figures given on p. 138.

LAND-REGISTERS PREPARED DURING 1896.

Name of Province	Area. Total in province for which records to be prepared.	Area. For which records prepared previously.	Area. For which records prepared within year under report.	No. of entries	No. of entries per feddan.	No. of villages for which records prepared.
	feddans					
Sharqia ...	532,418	—	81,670	54,844	0·66	59
Beheira ...	482,372	—	45,274*	3,792	0·08	11
	1,014,790		126,944	58,636		70

The operations had now passed beyond those of a survey of State lands, and were advancing in the direction of a cadastral survey on European lines ; not only were the revenue-producing lands recorded, but all other kinds of land were measured and mapped, both Government property and private land, areas reserved as being of public utility and others which were relieved of tax as being necessary for the dwellings of the taxpayers.

At the same time, however, that the technical work of land measurement was developed and organized, the second share of the preparation of the cadastral record was allotted to a separate department in the Ministry of Finance. Here the maps and their indices (the land-register) were received and the information re-arranged to form another register in which the total area owned by each proprietor and the amount of tax due from him was shown. This information was compared in the village with the areas and rates of tax previously recorded and any differences above five per cent. were inquired into ; the sale of Government land which had been encroached upon and the lease of other portions were also dealt with. This arrangement furnished an independent control upon the registers compiled by the surveyors, but deprived them of a valuable check on their work since the comparison between the area in possession of a proprietor before and after survey was not made by them. Gradually the necessity for this if mistakes were to be avoided and false statements detected became so evident that some inspectors prepared such comparative statements, although the work would be done again by another department.

* This includes some 20,000 acres of work on old system.

CHAPTER X.

General Account of the Cadastral Survey, 1897–1907.

The work of Sir William Willcocks' Commission (see p. 113) was completed by April 1897, and from the results a total rental value for each village was obtained by multiplying the area of the village, as given in the land-registers which then existed, by the mean rental value as fixed by the Commission. The total rental value of the land so arrived at was L.E. 16,356,000 on 4,550,181 feddans of land and the land-tax which was then being collected amounted to 28·64 per cent. of this rental value.* Before, however, the new rates of tax could be imposed a cadastral survey was necessary, since the areas recorded in the land-registers were known to be incorrect, partly on account of clerical and other errors, and partly on account of the ancient method of computing areas, which was everywhere still in use; moreover, the boundaries of villages and village subdivisions were uncertain and ill-defined, and the same subdivision frequently contained land of widely varying qualities. To impose the tax fairly under these conditions would have entailed assessing each plot, an impracticable task in a country where the land is so highly subdivided as in Egypt as may be seen from the statistics given at the end of this chapter; it was therefore necessary to make such new sub-divisions of from 50 to 100 feddans that the land within each was of the same rental value. Some time would be required to complete this survey, and temporary relief to last ten years was given to all "kharagi" land by reducing to one-third of the rental value all taxes which exceeded this proportion, at an annual cost to the state of L.E. 216,000.

In June, 1897, the re-assessment of the land-tax on a systematic plan had been definitely decided upon, and in 1898 the Commissioners of the Public Debt agreed to the grant of a sum of L.E. 216,000 a year for ten years in order to enable the Government to reduce all land-tax which was above the rate of L.E. 1·640 per feddan to that

* A. T. Mackillop. "Note on the Readjustment of the Land Tax in Egypt": Cairo 1907.

maximum rate.* This period of ten years was not determined on the basis of any reliable estimate of the time necessary for carrying out a cadastral survey of the six million feddans which remained to be mapped, but was arbitrarily determined. During this period the loss of revenue due to the reduction of excessive rates of tax would be made up to the Government from the reserve funds but at the end of the ten years the re-assessment of the land-tax was to be completed and the revenue secured by a more even distribution of it. This rigid time-limit necessitated a much more rapid rate of work than had previously been attained, for during the five years 1892–1896 only about 1,500,000 feddans had been surveyed and the work had been carried out in a much simpler and more elementary manner than was now necessary. Besides the limit of ten years for the period during which the remitted land-tax would be made up from the reserve funds, another restriction was imposed on the Survey by the instructions which were issued for the re-assessment of the land-tax. It was ordered that the re-assessment should be completed in every village of a province, and the final rates of tax for each "hod" published before the 31st of December, and that if any village was not complete by that date the new rates of tax for the whole province would be postponed for a year. If the maps and land-registers were forwarded to the Ministry of Finance in time for the Re-assessment Commissions to give the statutory notice, to examine the land and assess the rates of tax, to investigate complaints received after the proposed new rates had been notified, and lastly for the Ministry of Finance to approve and publish the new rates before the end of the year, then these new rates would come into force on the 1st of January five years after this publication of the new rates.

The dates on which the revised rates come into force are :—

Province.	Year.
Beheira and Sharqia	1905
Giza and Menufia	1906
Menufia and Fayum	1907
Qaliubia	1908
Daqahlia	1909
Qena and Aswan	1910
Girga and Assiut	1911
Minia and Beni Suef...	1912

* Cf. Decree of November 26, 1898

In 1897 the new system, which had been developed during 1896, was working regularly, and 362,660 feddans were surveyed in ten months, the year's total being probably rather over 400,000 feddans, of this the land-registers for 246,000 feddans were sent to the Settlement branch by the end of the year. In order to prepare for the re-assessment it was necessary to complete the work of this branch as quickly as possible in the provinces of Beheira and Sharqia and to expedite it 27 surveyors were transferred to the Settlement branch in this year, so that only 150 remained available for completing the remaining villages of these provinces and pushing on the survey of Gharbia. At this time the out-turn per surveyor was estimated to be 3,000 feddans per annum, and the opinion was expressed that this might be increased to 4,000 feddans. At the end of October there still remained eight villages in Sharqia province which were to be completed by the end of the year; in Beheira province twenty-five villages had not even been commenced, and eight were still under survey, but the completion of the whole of these thirty-five villages in the field was anticipated by the end of February, 1898. The land-registers of a hundred and fifty-two villages were also in course of compilation. In Gharbia 900,000 feddans besides a considerable area of waste or marshy land in the northern part of the province still remained to be measured, and one and a half years were estimated to be necessary in order to complete it with the whole of the available staff, which at this time included 51 engineers, 143 surveyors, 23 draughtsmen and computers, and 7 clerks. The theodolite traverse had been commenced in Giza province at the end of November, and there, use was made of the triangulation which had been prepared by the hydrographical survey (see Chap. VIII). As the primary object of the survey was now to provide a reliable basis for the re-assessment of the land-tax, every holding had if possible to be shown on the maps; thus the survey became to all intents a cadastral one, and it was necessary to bring the work as quickly as possible up to the standard of such surveys. The immediate result of this arrangement was to increase the importance of rapid work while accuracy had at the same time to be safeguarded; the various expedients which were adopted to obtain this result are described in the following chapters.

The Chief Inspector, who had come from the Revenue Survey of India in 1896, returned to that country in the autumn of 1897, having

initiated the theodolite traversing, the plotting of holdings in the field, the calculation of the area of each holding from the map sheets, and the compilation of the land-registers on the new forms.

Though the yearly out-turn had been greatly increased by the separation of the work into the Technical and Settlement branches, this arrangement tended to produce some delay and overlapping, so that a decision of the Council of Ministers dated June 8, 1898 ordered that the whole should be put on a wider basis by forming a Survey Department in which the triangulation, the revenue survey, and the reproduction of maps could be carried on in closer relation one to another, so that the work of each could be more easily planned so as to increase both the amount and the accuracy of the village survey.

The triangulation could now be prepared in advance of the detail survey, and of such accuracy as to furnish an effective control of it. Giza province had already been triangulated by the hydrographical survey and most of the theodolite traverse work there had been done; the chain survey was on the point of being commenced so that there was no time to revise any of this work or to check it in any elaborate manner. As already explained * the weakest points of the system employed by the hydrographical survey were the measurement of bases without any correction being introduced for temperature or for the error in the length of the steel band, the computation of observations by the observers, and the employment of magnetic azimuths.

The province of Giza contained nearly 250,000 feddans of cultivated lands which had to be surveyed as rapidly as possible on a scale of 1 : 4,000 in order that the land-tax might be re-assessed in 1900, so that it was necessary to utilize at once the triangulation which had been prepared, although its accuracy was not quite up to the standard requisite to control a chain survey which would be plotted on the above scale. In these circumstances, the best that could be done was to re-measure two sides of the triangulation network (one at Matania and another at Badreshein), to determine the azimuth of one side, and, from these data, to deduce the position of the triangulation points to which the traverse lines were joined and by which they were to be controlled. Subsequently, when the survey of Upper Egypt had been completed, the chain of second order triangles which was carried

* See Chapter VIII.

through this province showed that points near Giza were correctly placed within three or four metres, while those of the extreme north or south of the province were from sixty to eighty metres out of position. This error mainly affected the geographical position of the points and did not introduce any error into the areas of properties approaching the magnitude of ordinary errors of chain measurement.

1898.

During this year, the province of Gharbia, with the exception of the districts of Talkha and Sherbin in the north-east and Fua in the north-west, was surveyed in detail and the maps and land-registers were transmitted to the Settlement branch for completion. In Giza province also, a few villages were begun. By the end of the year, 948,000 feddans had been completed, being more than double the amount completed in 1897. This increase of work was partly due to an increased staff, but also to the work having been pushed on at high pressure. This is at all times a dangerous practice, and, where there is no efficient control, such as an accurate triangulation furnishes, errors accumulate rapidly ; the present case proved to be no exception to this and the points fixed by the theodolite traverses were only a partial check, not being themselves corrected by a triangulation of high accuracy. There were also too few points fixed by the traverse per square kilometre for the character of the land which was highly sub-divided, and the traverse lines were placed further apart than was prudent, in order to increase the rapidity of the work.

The last two villages of Sharqia province were finished this year and only three villages of Beheira province remained to be completed in 1899.

In 1898, authority was given to supply the public with copies of the maps on repayment, and this was done from the beginning of 1899, tracings of the villages in Sharqia and Beheira provinces being made, and also of those in Gharbia province until these latter were printed in the years 1899 to 1903.

1899.

In this year triangulation was commenced in the Fayum and a network of major triangulation consisting of 81 triangles having sides from 8 to 10 kilometres in length, was completed by the autumn.

The minor triangulation consisted of 330 triangles, the mean distance between points being 3,000 metres. A base was measured near the railway line at Seila in the east of the Fayum with a 100-metre steel-tape, since no more accurate base-measuring apparatus was yet available.

The detail survey of Gharbia was completed, the greater part of Giza province was also done, and two districts, Ashmun and Tala, in Menufia province, were commenced. The total area completed was 363,265 feddans, but little more than a third of that done in 1898, this being due to a change in the procedure of preparing the land-registers which was introduced. Since 1896, the map and its detailed index (the Daftar el Messaha) had been sent to the Settlement branch in order that the second part known as the Mizzania, in which all the plots belonging to each proprietor were collected under his name, should be compiled, though until then it had been done as a part of the field record work. This was now re-transferred from the Settlement branch to the Survey Department, so that from June 1, 1899, the whole work of land-measurement, the preparation of the land-registers and the comparison of the results with previous registers came under a single direction, and the maps and registers were transmitted together to the Ministry of Finance for approval and forwarding to the Mudiria office where new tax-registers (Mukallifa) were prepared on the basis of the new land-registers.*

This change greatly increased the amount of work to be done in order to complete the registers of each village, but made the detection of mistakes much easier since the final area found in the possession of each proprietor could be compared with that previously inscribed in his name and any considerable differences inquired into.

Not only was this additional work undertaken, but the maps and registers of 326 villages, which the Settlement branch had not been able to finish, needed revision and completion; since in Egypt, where small plots and fractions of plots are constantly changing hands, the revision of a village register after one or two years entails a large amount of alteration. Some of these villages had been surveyed some years before, so that the amount of correction necessary was very considerable. The total area which had thus to be revised

* See Circular of the Ministry of Finance, April 13, 1899. Appendix I.

was 788,253 feddans situated in 326 villages which had been surveyed at various times from 1895 to 1899.

Work in Menufia province was to a large extent suspended in order that this revision might be carried out as rapidly as possible, for the Re-assessment Commissions were proceeding with their work in Sharqia and Beheira provinces, and required the maps and registers of Gharbia and Giza before 1901. This threw a very heavy burden on the Department, which had only just been formed and was endeavouring to provide an efficient triangulation to control the field measurements; about double the area already measured remained to be surveyed besides that which needed revision, and the work of re-assessment was already in hand. The total area surveyed up to December 31, 1899, amounted to 2,589,000 feddans, while the total estimated area of cultivable land in Egypt was 7,390,000; the area still to be surveyed was therefore about 4,801,000 feddans. The work of revising the maps and registers which had been prepared in the previous years, and which had become out of date, makes it very difficult to arrive at any accurate estimate of the cost of the work at this time, and in 1899 an average of the time taken to survey and prepare the registers for a given area can alone be determined which, however, probably represents fairly the rate of work as a whole apart from revision.

Taking 100 feddans as a unit for purpose of comparison, the field survey and preparation of maps occupied 3·64 days at this time, while the computation and writing of the land-registers took 8·18 days, making up a total of 11·82 days; by the end of the year changes in the methods and procedure had reduced this total to 11 days, but even this rate was too slow to keep in advance of the re-assessment commissions and to finish the survey of the country within the period of ten years which had been laid down.

With these changes in procedure some other modifications were introduced which were incorporated in the order of the Ministry of Finance, dated April 13, 1899 (see Appendix I).

In this year for the first time the chain survey was being carried out in a district where triangulation was available as a control; for the province of Giza had been triangulated by the staff of the hydrographical survey during 1897. The advantage was at once apparent, although at the approximate methods of the triangulation already alluded to made it impossible in some cases where discrepancies were found

to decide whether the triangulation or the traverse work was in fault.

With the introduction of greater precision into the work, greater difficulty was experienced in accurately representing the smaller holdings. It will be remembered that this was also the experience of the cadastral surveyors of 1880, since, even when working on the scale of 1 : 2,000, they plotted the small plots to a larger scale (p. 86). It was decided in consequence to change the scale for the cadastral maps from 1 : 4,000 to 1 : 2,500, thus rendering it easier to show the smaller holdings, which are not uncommonly about 5 metres wide only (see p. 30). The following table shows the size of the different units of land area as represented on cadastral maps of the two scales and demonstrates the advantage which was obtained by using the larger scale :—

Unit.	Area in square metres.	Square millimetres on the scale of	
		1 : 4,000	1 : 2,500 *
1 Feddan..	4,200·333	256·1	657·1
1 Qirat	175·035	10·9	28·0
1 Sahm	7·293	0·49	1·17

The change made the maps more convenient and useful, but the work of both the surveyors and the staff of the Reproduction office was largely increased, since an area being represented by about 2½ times as large a map surface, increased to this extent the number of map sheets to be plotted, drawn, and reproduced. It would hardly have been practicable to do this with the staff available unless the work of plotting the traverse points had been greatly simplified and expedited by using the co-ordinatograph. †

The scale of 1 : 4,000 had originally been introduced in 1886 when the area of holdings was computed by mensuration (see p. 90), but now graphical methods were again in use and this scale, which is employed by the Revenue Survey of India, was too small for so highly subdivided a country as Egypt. The new scale, 1 : 2,500, is frequently employed

* See the imprint on Plan XXIX.

† See Chapter XV.

for cadastral maps of agricultural land in Europe, and is in use in England, where, however, the map is a topographical one and is not used with a property register. *

The printing of the village maps of Giza province was now commenced and thirty villages were published by the end of the year. Triangulation was not yet far enough advanced, nor was it sufficiently well connected to the "Venus Station," which is the fundamental longitude point on the Moqattam Hill near Cairo, to plot the sheets so as to form a continuous map, so that the group of sheets containing the lands of each village had to be printed separately as is done in the Revenue Survey of India.

1900.

In this year the major triangulation was carried on in Daqahlia and Qaliubia provinces and the minor triangulation was completed in the Fayum and commenced in the other provinces.

The detail survey was completed in the districts of Fua and Sherbin in Gharbia province, in the Ashmun district of Menufia province, and in all the districts of Giza province with the exception of six villages of Saff district; these had not been cultivated after the flood of 1899 which had been exceptionally low, for the land in these villages is higher than the average and consequently remains unwatered in years of low flood; it cannot then be cultivated and under such conditions the surveyors have no means of finding the boundaries of plots.

In all, 449,540 feddans were mapped and the land-registers for 972,214 feddans were compiled; 546,000 feddans of this latter number represented the remainder of the villages which had been received in the previous year for revision. In order to enable the survey to be carried out at a more rapid rate, another (fifth) inspectorate was authorized, and was formed by the end of the year.

Reorganization had by this time begun to show improved results and the average time taken in surveying and compiling registers was

* See Chapter XIX.

materially reduced for an area of 100 feddans, as will be seen from the following table:—

	Days.	
	1899.	1900.
Field survey and preparation of maps	3·64	2·70
Compiling and writing registers...	8·18	3·70
	11·82	6·40

1901.

By 1901, the work of the cadastral survey had become more systematized since the revision of the 800,000 feddans in Gharbia province had been completed, and triangulation had been carried sufficiently forward to be used as the basis and control of all field measurements in future work. All work now passed in one stage or another through the Computation office to ensure independent mathematical control, and such work as was not up to the specified standard of accuracy was returned to be reobserved. Menufia was the last province surveyed on the basis of theodolite traverses only and without triangulation; both this province and the Fayum were due for the re-assessment of their land-tax in 1902 and there was not time to triangulate and survey them both before that date, so that it was preferable to devote the time to completing that of the Fayum and then commencing work in the next province which would be taken up in survey. The major or second order triangulation of Daqahlia and Qaliubia was finished by the autumn and observations were then commenced in Qena and Girga provinces in Upper Egypt.

This abrupt movement from one end of Egypt to the other was extremely inconvenient from a surveyor's point of view, but was rendered necessary by the decision to build the Aswan Dam in order to form a reservoir in the Nubian portion of the Nile Valley where water could be stored to supplement the low-stage supply of the Nile. When the provinces of Daqahlia and Qaliubia had been finished, those of Beni-Suef and Minia would naturally have been the next to be undertaken, and triangulation would then have been conveniently extended southwards along the Nile Valley; but these two provinces and the northern part

of Assiut province were those in which the irrigation engineers were enabled by the Aswan Reservoir to replace the basin irrigation by perennial irrigation, thus enabling the land-owners to raise two or two and a half crops annually instead of one. This not only necessitated the expropriation of large quantities of land for canals and drains but changed the method of cultivation and greatly increased the value of the land. Consequently, it was very desirable that these changes should take place before the land-tax was re-assessed. The second order triangulation was therefore commenced in Qena, Aswan, and Girga provinces, a point at Luxor being taken as a point of departure since its latitude and longitude had been determined by the German Transit of Venus Expedition in 1874 (under Professor Auwers). All triangulation points in Upper Egypt were therefore referred to it until the chain of quadrilaterals could be carried down the valley to join the triangulation of that part of the Delta which had been already completed.

1902.

Base-lines were measured in this year at Gebelein in Luxor district, and at Ambir in Nag Hamadi district, and the greater part of the major triangulation in Qena and Girga provinces was completed, while the minor triangulation was finished in Daqahlia and Qaliubia and a good deal of it was done in Upper Egypt.

With considerable difficulty the chain survey and the land-registers of the Fayum and Menufia were ready for the Re-assessment Commissions by the summer, since the land in these provinces is very much subdivided and the removal of survey marks went on incessantly. In Qaliubia and Daqahlia, work went better and more quickly since fewer marks were removed; the triangulation was reliable and was completed in time to be utilized for the control of the theodolite traverses.

In this year, as all the provinces which were taken up had been properly triangulated, and as the methods of work had been definitely laid down, it became possible to publish all maps on a definite projection and as parts of a single scheme; each printed sheet therefore was henceforth full of detail and joined to the next sheets along each of its margins, whereas hitherto the map of each village had been printed as a separate group of sheets. This entailed a slight delay in publication, since a sheet frequently contained portions of two or three

villages and therefore could not be published until all these villages had been completed in the field ; on the other hand, the method was of great assistance in assuring the accuracy of the boundaries common to two villages, besides greatly facilitating the use of the maps for expropriation and for engineering work.

1903.

In 1903, the second order triangulation was completed from Dakka in Nubia to the north of Girga province, and to the south of Dakka a chain of minor triangulation was extended to Wadi Halfa where the Nile Valley is very narrow ; the administrative boundary between Egypt and the Sudan is situated at the north end of the village of Faras, but triangulation was continued southwards to Wadi Halfa in order to join that of the Sudan. About half the third order triangulation in Qena and Girga provinces was completed, besides the whole of that of Aswan province, and three bases were also measured. Work was considerably delayed by the Nile flood since in Upper Egypt the flood-plains are submerged by the inundation at the end of August and are not dry until the end of November, three months' field work being thereby lost.

The cadastral maps of Qaliubia and Daqahlia were completed.

1904.

The triangulation by the end of this year had been completed southwards as far as Wadi Halfa, and had moreover been carried through the provinces of Assiut, Minia and Beni-Suef, thus joining the triangulation of the Fayum which had been observed in 1899.

The lands of Aswan, Qena and Girga provinces are inundated annually by the flood water of the Nile in August and September, after which some further time must elapse before they are sufficiently dry for properties to be marked out, crops to be sown, and land measurement begun, the field-work of the survey had to be done and complaints investigated during the period December to July. It was therefore necessary to form an additional inspectorate—the sixth—of twenty-six surveyors to increase the area surveyed during the eight months when work was practicable, in order that the original programme of work might be maintained. By the end of the year, the provinces of Aswan

and Qena were finished and about one-third of that of Girga was surveyed.

Such was the pressure of work in the early part of 1904 that triangulation of both second and third order, theodolite traverse and chain survey were all in progress within a distance of some 30 or 40 kilometres, a state of affairs produced by the sudden transfer of work to Upper Egypt.

1905.

It was now possible to connect the triangulation of Upper Egypt which was based on the latitude and longitude of the point in Luxor that Professor Auwers had determined in 1874, with that of Lower Egypt which had been observed in the provinces of Qaliubia and Daqahlia in 1900 and 1901. This was done in March, 1905, along the line from the Great Pyramid at Giza to the Transit of Venus Station on the Moqattam Hill, when the following errors of closure were found :—*

Error of closure in latitude + 4″·12
Error of closure in longitude — 11″·72

The whole network of triangulation could now be made consistent and it was for the first time possible to prepare a map of Egypt based on a continuous and reliable triangulation extending from Wadi Halfa to the Mediterranean. This was at once put in hand on the scale of 1 : 50,000, and, up to the present time all the 145 sheets have been published except some twenty containing the western portion of the Delta, which is being re-surveyed. After this connection had been made, the triangulation was carried into Sharqia province which was to be re-surveyed, as the former survey of 1892-1896 was found to be inadequate, although with no little trouble the land-tax had been re-assessed with its aid. Now, however, in 1905 the Legislative Council on the proposition of its members from Sharqia province, requested the Government to re-survey it in the same way as was being done in Upper Egypt. In the cadastral work the province of Girga was finished as well as that of Assiut, and the province of Minia was commenced.

* For a further discussion of these differences and the method of dealing with them, see Chapter XV.

1906.

The triangulation of Sharqia province was completed, and preparations were made to extend it over Menufia province into Beheira.

The provinces of Minia and Beni Suef were completed by the cadastral survey except for some villages which had to be finally revised after the flood waters had receded and the land had become dry enough to work upon.

1907.

The triangulation of Menufia and Beheira provinces was completed and the staff were able at the end of this year to move into Gharbia, the only province in which there is no second order triangulation as yet, but here, too, it will have been completed by the end of 1908.

The remaining villages of Beni Suef were completed in the early months of the year, and, by the end of June, the maps and registers were transmitted to the Ministry of Finance, thus completing the cadastral survey of the whole country in exactly ten years from the date on which the Survey Department had been formed.

Taking, then, the period from the beginning of 1899 to the end of 1906, an area of four million feddans has been surveyed, as well as another million feddans in Gharbia, of which the revision and bringing up to date of both maps and land-registers amounted to almost as much work as a new survey. Nearly five million feddans, therefore, or about 20,000 square kilometres, have been mapped on the scale of 1 : 2,500, and the holdings separately measured and recorded in the course of eight years, besides compiling the land-registers for the same area and printing and publishing the maps. The following table shows the areas surveyed, the scale of the maps, and the number of sheets published. At first the scale used was 1 : 4,000, as in Revenue Survey of India, but the extreme subdivision of the land into small holdings of which on the average 40 per cent. are under half a feddan, and 50 per cent. more are between this and five feddans, necessitated the employment of a larger scale, so 1 : 2,500 was adopted.

Province.	Area feddans.	Scale of maps.	No. of sheets.	Period of Survey	Remarks.
Sharqia *	892,512	1 : 2,500	2,840	1906–1908	Triangulation.
Sharqia	814,442	1 : 4,000	*	1892–1899	No triangulation.
Beheira	1,087,001	,,	*	1893–1900	,,
Gharbia	1,563,231	,,	2,375	1897–1901	,,
Menufia †	374,223	1 : 4,000 and 1 : 2,500	2,197	1898–1902	,,
Giza	244,883	1 : 4,000	244	1898–1901	Triangulation.
Fayum	412,983	1 : 2,500	2,287	1900–1902	,,
Qaliubia	220,620	,,	777	1902–1903	,,
Daqahlia	627,331	,,	2,232	1902–1903	,,
Qena	401,282	,,	1,575	1903–1904	,,
Aswan...	134,001	,,	1,073	1904	,,
Girga	355,080	,,	1,302	1904–1905	,,
Assiut	473,864	,,	1,696	1904–1905	,,
Minia	463,579	,,	1,627	1905–1906	,,
Beni Suef	252,440	,,	850	1905–1907	,,

The total number of map-sheets printed is therefore :—

Map-sheets on scale 1 : 4,000	3,611
Map-sheets on scale 1 : 2,500	17,964
Total...	21,575
Estimated number of sheets of Beheira and Sharqia, to be printed, scale 1 : 2,500	3,200
Grand total...	24,775

As a result of this survey the area of the cultivable lands is now known with much greater accuracy than hitherto ; some waste lands are of course included, but in most cases they are considered to be reclaimable sooner or later. The areas of both districts and provinces are given in the following tables in which public and private lands,

* Maps were not printed until these provinces were re-surveyed in 1907-9.

† Ashmun district was surveyed on 1 : 4,000, the other districts on 1 : 2,500.

village sites, and state lands are included, but the Nile and the lakes of the Delta and the Fayum are not:—

Province.	Districts.	Area in Feddans of District.	Area in Feddans of Province.
Beheira *	Abu Hommos	259,032	1,087,001
	Damanhur	108,612	
	Delingat	88,524	
	Teh el Barud	74,192	
	Kafr el Dawar... ...	262,518	
	Kom Hamada	82,369	
	Shubrakhit	65,777	
	Rosetta	123,542	
Gharbia	Fua	83,876	1,563,231
	Dessuq	125,536	
	Zifta	60,019	
	El Borollos	39,798	
	Tanta...	113,243	
	El Santa	60,293	
	Talkha	111,439	
	Sherbin	409,826	
	Kafr el Zayat	74,912	
	Kafr el Sheikh... ...	349,608	
	Mehalla el Kobra ...	134,681	
Daqahlia	Damietta	57,774	627,331
	Aga	71,725	
	El Mansura	80,859	
	Mit Ghamr	83,341	
	El Simbellawein ...	128,422	
	Dekernes	205,210	
Sharqia †	Miniet el Qamh ...	78,912	892,512
	Belbeis	108,322	
	El Zagazig	219,169	
	Kafr el Saqr	142,074	
	Hehia	71,970	
	Faqus	272,065	
Menufia	Tala	79,813	374,223
	Ashmun	72,639	
	Menuf	79,154	
	Shibin el Kom... ...	71,343	
	Quesna	71,274	
Qaliubia	Dawahi Masr	17,330	220,618
	Nawa...	73,048	
	Qaliub	56,567	
	Tukh...	73,673	
Giza	Embaba	92,059	244,883
	El Giza	49,913	
	El Saff	46,817	
	El Ayat	56,094	

* From the survey of 1893-1900.

† Under re-survey, four villages unfinished so area may be slightly altered

Province.	Districts.	Area in Feddans of District.	Area in Feddans of Province.
Fayum	El Fayum...	87,239	412,983
	Etsa	181,970	
	Sennures	143,774	
Beni Suef	Beni Suef...	98,451	252,440
	El Wasta	70,205	
	Biba	83,784	
Minia	Abu Qurqas	57,389	463,579
	Beni Mazar	95,125	
	El Fashn	63,672	
	Maghagha	77,780	
	El Minia	75,002	
	Samalut	94,611	
Assiut	Abutig	60,124	473,864
	Assiut	55,079	
	El Badari...	35,825	
	Deirut	85,326	
	Abnub	63,105	
	Mallawi	89,303	
	Manfalut	85,102	
Girga	Akhmim	37,110	355,080
	Baliana	72,782	
	Girga	83,688	
	Sohag	65,579	
	Tahta...	95,921	
Qena	Dishna	69,218	401,282
	Esna	48,795	
	Luxor	71,131	
	Nag Hamadi	94,901	
	Qena	52,142	
	Qus	65,095	
Aswan...	Edfu	78,948 *	134,001
	Aswan	28,105	
	El Derr	26,948	
	Grand total		7,383,028

Throughout the country a considerable reduction of area had taken place owing to the holdings having been correctly computed ; an even larger area was relieved of tax since many canals and roads which were really of public utility had been included in the lands of private landowners who had been obliged to pay tax on them. On the other hand much new land had been taken into cultivation as more and

* Including Kom Ombo 30,000 feddans.

more water became available. It is not possible to separate these different causes, but the areas in feddans of each province before and after survey can be stated :—

Province.	Before Survey.				After Survey.				Difference.
	Private.	Public utility	Govt. Land.	Total.	Private.	Public utility	Govt. Land.	Total.	
Beheira	—	—	—	1,087,001	—	—	—	*	—
Gharbia... ...	—	—	—	1,456,646	—	—	—	1,563,231	+ 106,585
Daqahlia ...	524,477	10,558	58,773	593,808	516,661	22,290	88,380	627,331	+ 23,523
Sharqia	—	—	—	814,442	—	—	—	*	—
Menufia... ...	—	—	—	388,484	—	—	—	374,223	— 14,261
Qaliubia ...	197,704	9,857	7,148	214,700	190,896	11,860	16,701	220,618	+ 5,918
Giza	—	—	—	218,862	—	—	—	244,883	+ 26,021
Fayum	—	—	—	383,961	—	—	—	412,983	+ 29,022
Beni Suef ...	238,374	6,908	11,020	256,302	223,343	15,156	13,941	252,440	— 3,862
Minia	398,423	4,595	34,399	437,418	382,830	23,673	57,075	463,579	+ 26,161
Assiut	424,307	8,383	52,915	483,604	403,791	23,283	46,790	473,864	— 9,740
Girga	331,315	14,247	21,152	366,714	309,345	18,697	27,038	355,080	— 11,634
Qena	354,404	15,175	19,852	389,430	337,492	21,058	42,733	401,282	+ 11,852
Aswan	71,142	2,950	17,623	91,715	66,868	7,439	29,694	104,001	+ 12,286

* Under re-survey.

Cost of the Survey.

It is difficult to state accurately the cost of the Cadastre and more difficult to apportion the share of work which not only was used for the cadastral survey, but also for other classes of surveying work.

The triangulation formed the basis and the control not only of the cadastral maps, but also of the topographical maps on 1 : 10,000, 1 : 50,000 and other scales ; on the other hand, a certain sum should be debited to the Cadastre for clerical and administrative work of the central office at headquarters, which did the same for the other branches of the department ; in any case, this addition would be small and might be safely put at about L.E. 1,500–2,000 per annum at the outside.

If, however, the cost of the following classes of work are included, a very close estimate will be obtained to the true cost of the Cadastre up to the end of 1907, when large-scale maps of the whole of the cultivable lands of Egypt had been prepared, and the land-registers compiled, while the same had also been done for 400,000 feddans in Sharqia province, which has just been re-surveyed:—

(1) Second order triangulation of whole country except Gharbia province.
(2) A chain survey of the whole of the cultivable land of Egypt on the scale of 1 : 4,000 or 1 : 2,500.
(3) The re-survey of 400,000 feddans in Sharqia province on the scale of 1 : 2,500.
(4) Maps drawn and land-registers prepared for the above areas.

All salaries, allowances, transport, cost of instruments, stores, and the hire of boats and offices are included, but not the reproduction of the cadastral maps, for the cost of this is given separately in Chapter XVIII.

Year.	Triangulation.	Cost of computation.	Traverse, Chain survey and compilation of registers.	Total.
	L.E.	L.E.	L. E.	L.E.
1892	—	—	3,500	3,500
1893	—	—	11,650	11,650
1894	—	—	18,206	18,206
1895	—	—	21,872	21,872
1896	—	—	22,000	22,000
1897	—	—	22,500	22,500
1898	2,300	—	21,300	23,600
1899	— *	—	26,700	26,700
1900	— *	920	25,830	26,750
1901	4,453	1,205	26,342	33,000
1902	4,928	2,079	24,296	31,303
1903	5,025	2,303	26,554	33,882
1904	4,244	2,325	30,627	36,196
1905	3,547	2,815	36,095	42,457
1906	4,101	3,280	33,913	41,294
1907	4,493	3,442	38,579	46,514
Total	33,091	18,369	389,964	441,424

For this total of L.E. 441,424 the whole country has been mapped and land-registers prepared; a network of second order triangulation has been observed over the whole country except a part of northern Gharbia, which has been reconnoitred and marked, but was not observed until the end of 1908; the third order triangulation has been observed everywhere except in a very small part of Beheira and in Gharbia; on the other hand 400,000 feddans have been traversed and re-surveyed, and more than half Beheira province has been traversed in readiness for re-survey in 1908 and 1909. The area surveyed may be classified as follows :—

	Feddans.	Hectares.
Reported as surveyed up to December 31, 1899 ...	2,589,000	1,087,596
Re-surveyed in 1900 in Gharbia...	800,000	336,066
Surveyed between January, 1900, and June, 1907 ...	4,803,000	2,017,660
Re-surveyed in Sharqia in 1907	400,000	168,033
	8,592,000	3,609,355

* Included in cost of chain survey.

The total area surveyed almost wholly without triangulation up to the end of 1899 was 3,389,000 feddans, and the cost of this amounted to 37 milliemes per feddan, or L.E. 3·700 per hundred feddans.

The whole cost of the 8,592,000 feddans which includes some re-survey, amounted to L.E. 441,424, which is equivalent to 51 milliemes per feddan, so that the average cost was about 50 milliemes per feddan, or L.E. 5 per hundred feddans including all the cost of the triangulation.

The land-tax in 1907 amounted to about L.E. 5,060,000, so that the whole cost of the survey, including triangulation, amounted to about 9 per cent of a single year's land-tax at the present time.

The statistics which have been given furnish an idea of the cost of the work but do not suffice for making a comparison between the cost of the Egyptian survey and those of other countries. The rates of pay, conditions of work, facilities for housing, transport, communication, and a number of other factors enter so largely into the discussion that any attempt to compare them will be of small value. The following tables give the numbers and rates of pay of engineers, surveyors and computers in the Department both Egyptians and Europeans. In these are included those employed on third order triangulation, traverse, and chain survey, as well as a few who worked on topographical work :—

NUMBER AND RATES OF PAY OF ENGINEERS IN THE SURVEY DEPARTMENT.

Monthly rate of pay.	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
L. E.										
Under 4	4	3	2	—	—	3	1	1	—	—
4— 8	27	28	25	29	35	39	38	54	55	43
	—	—	—	—	*1*	—	—	—	—	—
9—12	6	6	11	15	15	14	13	25	27	25
	1	*1*	—	—	—	—	—	—	—	*1*
13—19	—	—	1	1	2	3	1	3	3	9
			1	*1*	*1*	*2*	*1*	—	*1*	—
20—30	—	—	—	—	—	1	2	2	2	1
	1	*1*	—	—	—	—	*1*	*1*	*1*	*1*
Total... ...	37	37	39	45	52	60	55	85	87	78
	2	*2*	*1*	*1*	*2*	*2*	*2*	*1*	*2*	*2*
GRAND TOTAL... ...	39	39	40	46	54	62	57	86	89	80

Figures in italics are Europeans.

Number and Rates of Pay of Surveyors in the Survey Department.

Monthly rate of pay.	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
L. E.										
Under 4	136	122	119	152	173	206	190	208	182	73
4 — 8	21	18	10	7	9	23	43	57	80	237
Total... ...	157	140	129	159	182	229	233	265	262	310

Number and Rates of Pay of Computers in the Survey Department.

Monthly rate of pay.	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
L. E.										
Under 4	5	9	17	28	52	52	40	46	52	5
	—	—	—	*2*	—	—	—	*2*	*1*	—
4 — 8	—	—	—	—	5	13	22	31	40	66
	—	—	—	*1*	*3*	*3*	*2*	*5*	*8*	*13*
8·5—18	—	—	—	—	—	1	3	2	4	2
	—	—	—	—	—	—	*1*	—	—	—
Total... ...	5	9	17	28	57	66	65	79	96	73
				3	*3*	*3*	*3*	*7*	*9*	*13*
Grand Total... ...	5	9	17	31	60	69	68	86	105	86

Figures in italics are Europeans.

Cadastral Survey Statistics for Lower and Upper Egypt.

Cadastral Survey Statistics for Lower Egypt.

Province.	District.	No. of villages.	Date of survey.	Area. Feddans.	Area. Hectares.	Difference from previous survey. Excess.	Difference from previous survey. Deficit.	Number of plots. Total.	Number of plots. Under 12 Qirats.	Number of plots. Between 5 Feds. and 12 Qirats.	Number of plots. Above 5 Feds.	Average size of plot. Feds.	Time of survey in days per 100 Feds. Field work.	Time of survey in days per 100 Feds. Registers.	Cost of survey in L. E. per 100 Feds. Maps. L. M.	Cost of survey in L. E. per 100 Feds. Registers. L. M.
						Feds.	Feds.									
Beheira ...	Abu Hummos ...	34	— 93 — 99	259,032	108,814·9											
	Damanhur	51	— 94 — 00	108,612	45,626·0											
	El Delingat... ...	24	— 95 — 99	88,524	37,187·4											
	Teh el Barud ...	52	— 95 — 99	74,192	31,166·8											
	Kom Hamada ...	55	— 97 — 99	82,369	34,601·8			NO RECORDS.								
	Kafr el Dawar ...	15	— 93 — 00	262,518	110,279·3											
	Rosetta...	20	— 94 — 00	123,542	51,885·3											
	Shubrakhit	60	— 94 — 99	65,777	27,631·8											
	Ushur Iskandria..	4	— 93 — 00	22,435	9,424·6											
	Total for Mudiria	315		1,087,001	456,617·9											
Gharbia ...	El Borollos * ...	2	20-10-06—12-12-07	39,798	16,718·5	2,996	—	3,741	1,277	1,850	614	1·6	2·0	1·5	0·637	0·034
	Desuq	37	23-11-97—20-5-00	125,536	52,735·5	6,728	—	22,183				5·6				
	Fua	19	7-6-00—27-12-00	83,876	35,234·9	—	18,674	5,805				14·4				
	Kafr el Zayat ...	56	3-4-97—31-1-01	74,912	31,469·2	—	905	35,025				2·1				
	Kafr el Sheikh ...	82	15-1-98—14-6-00	349,608	146,864·4	83,042	—	12,879				27·1				
	El Mahalla el Kubra	60	28-1-98—1-5-01	134,681	56,577·2	—	2,896	26,892	NO RECORDS.			5·0	NO RECORDS.			
	Sherbin..	26	2-5-99—30-6-01	409,826	172,160·9	50,354	—	14,927				27·4				
	Santa	51	18-7-97—11-12-00	60,293	25,328·1	—	1,153	39,813				1·5				
	Tanta	63	26-5-97—16-5-01	113,243	47,571·4	—	2,070	58,680				2·0				
	Talkha	47	9-6-98—13-5-00	111,439	46,813·6	—	5,323	13,769				8·1				
	Zifta	57	21-11-97—5-6-01	60,019	25,213·0	764	—	37,305				1·6				
	Total for Mudiria	500	3-4-97—6-9-01	1,563,231	656,686·7	112,863	—	271,019				8·8				

DAQAHLIA	Aga	67	11-1-03—23-10-03	71,725	30,130·5	—	1,056	25,073	6,542	16,248	2,283	2·8	3·4	2·9	0·851	0·499
	Dekernes	72	28-10-02-31-12-03	205,210	86,205·2	34,660	—	51,092	20,634	26,692	3,766	1·0	3·6	1·7	0·736	0·239
	Faraskur	35	5-6-02—1-10-03	57,774	24,269·9	2,357	—	11,149	3,473	5,606	2,070	5·2	4·8	2·7	1·076	0·349
	El Mansura	64	21-4-02—23-11-03	80,859	33,967·5	121	—	25,192	7,662	15,360	2,170	3·2	4·2	2·7	0·961	0·468
	Mit Ghamr	81	3-6-02—22-11-03	83,341	35,010·1	—	1,139	35,813	10,672	21,769	3,372	2·3	6·5	6·0	1·286	0·846
	El Simbellawein .	83	5-4-02—5-12-03	128,422	53,947·9	—	1,420	35,828	9,397	21,725	4,706	3·6	4·1	1·6	1·200	0·297
	Total for Mudiria	402	5-4-02—31-12-03	627,331	263,531·1	36,523	—	184,147	58,380	107,400	18,367	3·5	4·1	2·9	1·018	0·450
MENUFIA	Ashmun	54	16-1-99-18-5-01	72,639	30,514·4	—	4,573	41,951	—	—	—	1·7	—	—	—	—
	Menuf	65	1-7-00—10-5-02	79,154	33·251·2	—	2,824	64,429	22,156	40,743	1,530	1·5	6·1	10·6	1·288	1·393 †
	Quesna	61	8-12-00—30-7-02	71,274	29,941·0	—	2,612	38,005	10,499	25,178	2,328	1·9	6·9	7·2	1·646	1·017 †
	Shibin el Kom ...	60	14-2-01—24-2-03	71,343	29,970·0	—	1,226	59,181	22,194	35,681	1,306	1·2	8·8	6·0	2·053	0·997 †
	Tala	65	15-12-98—10-11-01	79,813	33,528·1	—	3,026	58,361	—	—	—	1·1	—	—	—	—
	Total for Mudiria	305	15-12-98—24-2-03	374,223	157,204·7	—	14,261	261,927	—	—	—	1·5	—	—	—	—
SHARQIA †	Belbeis	60	6-4-06—2-4-08	108,322	45,504·2	3,783	—	36,159	15,995	18,029	2,135	3·0	5·9	4·6	1·511	1·103
	Faqus	46	6-8-06— — —	250,065	105,048·1	—	—	37,598	16,193	16,434	4,971	6·7	5·0	4·0	1·237	0·970
	Hehia	52	16-9-06 — —	71,970	30,233·4	—	—	21,923	7,939	11,580	2,404	3·3	8·5	3·0	2·005	0·838
	Kafr Saqr	53	13-7-06— — —	141,074	59,262·8	—	—	31,340	9,181	17,032	5,127	4·5	7·3	4·0	1·492	0·800
	Mina el Qamh ...	85	7-1-06—19-8-07	78,912	33,149·6	192	—	35,659	12,557	20,409	2,693	2·2	6·2	2·6	1·483	0·642
	El Zagazig	69	17-7-06— — —	180,548	75,845·1	—	—	39,501	15,008	20,269	4,224	4·6	4·4	6·8	1·231	1·615
	Total for Mudiria	365	7-1-06— — —	830,891	349,043·2	—	—	202,180	76,873	103,773	21,534	4·1	6·2	4·2	1·493	0·995
QALIUBIA	Dawahi Masr ...	14	12-6-02—4-4-03	17,330	7,280·0	—	115	4,830	1,667	2,522	611	3·6	5·3	2·4	1·221	0·383
	Nawa	41	7-5-02—6-4-03	73,048	30,686·2	9,594	—	25,976	9,589	14,545	1,842	2·8	3·3	2·6	0·829	0·435
	Qaliub	35	18-11-02—30-6-03	56,567	23,762·8	—	2,230	18,146	4,652	11,677	1,817	3·1	5·0	2·8	1·052	0·501
	Tukh	59	17-2-02—19-7-03	73,673	30,948·8	—	2,501	40,427	16,452	21,849	2,126	1·8	7·1	5·4	1·582	0·739
	Total for Mudiria	149	17-2-02—19-7-03	220,618	92,677·8	4,748	—	89,379	32,360	50,593	6,426	2·8	5·2	3·3	1·171	0·514

* From new survey, 1907. † Some villages are omitted. ‡ Re-survey not completed.

Cadastral Survey Statistics for Upper Egypt.

Province.	District.	No. of villages.	Date of survey.	Area. Feddans.	Area. Hectares.	Difference from previous survey. Excess. Feds.	Difference from previous survey. Deficit. Feds.	Number of plots. Total.	Number of plots. Under 12 Qirats.	Number of plots. Between 5 Feds. and 12 Qirats.	Number of plots. Above 5 Feds.	Average size of plot. Feddans.	Time of survey in days per 100 Feds. Field work.	Time of survey in days per 100 Feds. Registers.	Cost of survey in L. E. per 100 Feds. Maps. L.E. M.	Cost of survey in L. E. per 100 Feds. Registers. L.E. M.
Giza	Ayat	42	19-12-98—14-10-00	56,094	23,564·1	3,418	—	26,992	12,083	13,269	1,640	2·1	NO RECORDS			
	Embaba	44	22-12-98—28-2-01	92,059	38,672·4	9,546	—	35,210	10,773	21,733	2,704	2·6				
	Giza	35	23-6-98—3-3-01	49,913	20,967·6	4,943	—	17,975	4,825	11,612	1,538	2·8				
	Saff	29	19-12 98—24-5-01	46,817	19,667·0	8,114	—	21,311	6,900	13,184	1,227	2·2				
	Total for Mudiria	150	23-6-98—24-5-01	244,883	102,871·1	26,021	—	101,488	34,581	59,798	7,109	2·4				
Fayum ...	Etsa	31	6-2-01—5-7-02	181,970	76,642·5	25,044	—	40,080	15,655	21,072	3,353	4·5				
	Fayum	25	8-1-01—3-9-02	87,239	36,647·6	1,342	—	39,469	18,444	18,781	2,244	2·2				
	Sennures	29	12-10-00—10-7-02	143,774	60,397·0	2,636	—	45,576	20,412	22,443	2,721	3·2				
	Total for Mudiria	85	12-10 00—3-9-02	412,983	173,687·1	29,022	—	125,125	54,511	62,296	8,318	3·3				
Beni Suef...	Beni Suef	58	19-10-05—29-4-07	98,451	41,357·5	—	3,086	41,758	15,075	23,282	3,401	2·4	3·2	4·2	0 758	0 948
	Beba	68	29-7-05—7-11-06	83,784	35,196·2	652	—	51,045	26,603	22,048	2,394	1·6	4·2	6·0	0 936	1 114
	Wasta	43	11-1-06—29-4-07	70,205	29,491·9	—	1,428	39,205	16,990	19,795	2,420	1·8	3·6	5·7	0 803	1 230
	Total for Mudiria	169	29-7-05—29-4-07	252,440	106,045·6	—	3,862	132,008	58,668	65,125	8,215	1·9	3·7	5·3	0 832	1 097
Minia ...	Abu Qurqas... ...	49	14-5-05-29-6-06	57,389	24,108·1	2,351	—	19,176	7,796	9,520	1,860	3·0	3·0	2·4	0 550	0 437
	Beni Mazar	46	30-4-05—8-7-06	95,125	39,960·4	881	—	23,252	9,246	11,536	2,470	4·1	3·0	1·5	0 600	0 287
	Fashn	38	16-8-05—5-12-06	63,672	26,747·5	2,766	—	18,587	7,666	8,920	2,001	3·4	2·8	2·9	0 537	0 448
	Maghagha	49	17-6-05—29-9-06	77,780	32,674·0	5,777	—	21,096	8,151	11,129	1,816	3·7	2·0	2·9	0 427	0 600
	Minia	38	27-5-05—19-12-06	75,002	31,507·1	6,551	—	20,836	7,823	10,642	2,371	3·6	2·1	3·6	0 541	0 742
	Samalut	44	26-4-05—11-9-06	94,611	39,744.5	7,834	—	20,587	5,971	11,171	3,445	4·6	2·0	2·0	0 457	0 357
	Total for Mudiria	255	26-4-05—19-12-06	463,579	194,741.6	2,6169	—	123,534	46,653	62,918	13,963	3·7	2·5	2·6	0 519	0 478

Assiut ...	Abu Tig ...	35	18-4-04—15-11-05	60,124	25,257·1	—	2,257	36,542	11,873	22,726	1,943	1·6	4·2	5·8	0 864	1 063
	Assiut	28	1-12-04—31-12-05	55,079	23,137·7	—	1,254	39,177	16,729	20,790	1,668	1·4	5·0	4·9	1 226	1 230
	Badari	27	21-1-05—31-12-05	35,825	15,049·5	—	4,260	22,678	9,399	12,118	1,161	1·6	5·2	9·1	1 197	1 538
	Deirut	53	8-1-05—15-12-05	85,326	35,844·0	—	2,651	41,370	16,863	21,828	2,679	2·1	3·2	2·8	0 681	0 537
	Abnub	28	8-11-04—15-12-05	63,105	26,509·3	5,829	—	37,608	15,691	20,361	1,556	1·7	3·3	3·9	0 847	0 879
	Mallawi	52	22-10-04—14-11-05	89,303	37,514·8	—	5,536	33,853	13,991	17,509	2,353	2·6	3·2	2·8	0 643	0 522
	Manfalut	49	1-12-04—9-12-05	85,102	35,749·9	—	1,611	40,655	17,564	20,695	2,396	2·1	3·6	5·8	0 788	0 940
	Total for Mudiria	272	18-4-04—31-12-05	473,864	199,062·3	—	11,740	251,883	102,110	136,927	13,746	1·9	4·0	5·0	0 892	0 958
Girga ...	Akhmim	24	20-3-04—30-3-05	37,110	15,589·3	—	2,778	23,724	8,668	14,085	971	1·6	3·3	6·5	0 844	0 997
	Baliana	36	8-2-04—19-7-05	72,782	30,574·5	—	1,932	39,736	16,845	20,584	2,307	1·8	3·4	6·0	0 727	1 060
	Girga	60	4-2-04—18-7-05	83,688	35,155·9	—	6,279	46,717	16,584	27,025	3,108	1·7	4·7	3·5	1 016	0 760
	Sohag	46	7-3-04—29-6-05	65,579	27,548·7	—	2,069	48,048	20,175	26,218	1,655	1·4	3·4	5·3	0 681	1 065
	Tahta	61	20-7-04—25-7-05	95,921	40,291·8	1,423	—	59,454	22,646	33,933	2,875	1·6	3·6	4·7	0 758	0 720
	Total for Mudiria	227	4-2-04—25-7-05	355,080	149,163,2	—	11,635	217,679	84,918	121,845	10,916	1·6	3·7	5·2	0 805	0 920
Qena	Deshna...	15	13-9-03—27-10-04	69,218	29,077·3	7,503	—	39,119	16,017	21,073	2,029	1·8	3·5	2·7	0 797	0 501
	Esna	18	11-10-03—27-10-04	48,795	20,497·9	—	1,963	23,816	10,678	11,600	1,538	2·0	8·6	3·3	1 731	0 614
	Luxor	17	9-10-03—29-10-04	71,131	29,880·9	2,317	—	22,002	9,719	10,191	2,092	3·2	4·5	3·7	0 926	0 629
	Nag Hamadi ...	35	1-9-03—4-1-05	94,901	39,866·3	229	—	47,414	17,679	26,712	3,023	2·0	4·7	3·6	0 997	0 577
	Qena	20	19-9-03—30-9-04	52,142	21,906·9	2,086	—	31,746	13,018	16,863	1,865	1·6	6·6	3·2	1 450	0 580
	Qus	28	9-10-03—17-10-04	65,095	27,345·9	1,679	—	36,508	15,272	19,037	2,199	1·8	4·2	3·2	0 959	0 616
	Total for Mudiria	133	1-9-03—4-1-05	401,282	168,575·2	11,851	—	200,605	82,383	105,476	12,746	2·0	5·4	3·3	1 143	0 586
Aswan ...	Aswan	20	4-5-04—27-12-04	28,105	11,806·4	1,725	—	10,931	5,629	4,373	929	2·6	5·7	5·5	1 207	0 752
	Derr	37	15-2-04-25-12-04	26,949	11,320·4	9,172	—	6,370	2,086	2,729	1,555	4·2	4·6	5·1	1 322	0 873
	Edfu	17	16-1-04—4-12-04	48,949	20,562·6	1,390	—	21,438	7,702	12,050	1,686	2·3	6·5	4·4	1 280	0 567
	Total for Mudiria	74	16-1-04—27-12-04	104,003	43,689·4	12,287	—	38,739	15,417	19,152	4,170	2·7	5·6	5·0	1 273	0 731

CHAPTER XI.

The Standards of Length.

Although a decree had been published in April 28, 1891* laying down the metric equivalents for each of the measures of length in use in the country, no standard *diraa* or metre was made, of which the error was accurately known by comparison with the international standards. There was certainly the 4-metre base-measuring bar of Brünner-Ibañez, but this had not been used for some years; the triple-metres used by the Cadastre of 1878–1888 were lying in the stores of the Ministry of Public Works, and another metre bar was in the Engineering Department of the Ministry of War.

The inconvenience of having no reliable standard of length was soon felt during the work of the Geological Survey in 1896, since the errors of the reputed standards above mentioned which existed in Egypt had either never been determined or the original certificates had been lost. The 4-metre bar by Brünner-Ibañez should, perhaps, be excepted, but it was not at the time in a satisfactory condition; no records existed of how it had been treated since it had been compared with the Spanish bar at Madrid in 1862, nor did a sufficient trained staff exist to use it efficiently. In 1897, therefore, one of the steel triple-metres purchased in Italy about 1878 for the Cadastre of that time was sent to the Standards Office of the Board of Trade, London, and there compared with the International Standard Metre No. 16, in July 1898.

The result was that the lengths of the three bars of the triple-metre were found to be as stated in the copy of the certificate No. 1 which is given in Appendix II. In order to project the geological map sheets correctly, a metre rule of German silver divided to millimetres was obtained in 1897, and its length was found at the Standards Office of the Board of Trade to be 1·00004 metre from centre to centre of the terminal lines at 0°C. as stated in the copy of the certificate which is printed in Appendix II (No. 2.)

* See Appendix I.

By means of these it was possible to determine the length of a longer unit of length with moderate accuracy if required.

The work of the Geological Survey did not demand topographical surveying of high accuracy, since it was engaged in working out the main geological structure of the country, and, with this object, the geologists were less in the Nile Valley than in the desert, where the measuring-wheel, graphical triangulation carried out with the plane-table, and traverses plotted by means of a time scale, provided results of sufficient accuracy when they were controlled by astronomical observations to determine the latitude and these were frequently made. At the same time it was probable that before long mapping would be commenced in the valley, so that it seemed desirable to prepare for doing so by determining astronomically the position of a series of points in the valley and by making a set of base-measuring rods which would enable a base to be measured with fair accuracy and at a far less cost than that which the Brünner-Ibañez bar would entail if used. The very satisfactory results obtained with 5-metre fir rods in Germany * suggested the use of these until such time as a general survey of the country on the basis of an accurate triangulation should be undertaken and apparatus capable of attaining higher precision in the results should become necessary.

Four pieces of well-seasoned pine were made into four measuring-rods each five metres long; they were sawn longitudinally into four sections by two cuts at right angles to one another; the first and third sections were then reversed, and the four pieces were screwed together again. By this means, warping was prevented, or at least reduced to a minimum, and, even in the dry summer weather, no difficulty from this cause was experienced. When finished, the rods were five centimetres square in the centre tapering to three and a half centimetres square at each end. The ends were shod with caps of hardened steel ending in a chisel-shaped edge, that at one end of the rod being at right angles to the one at the other end; thus, when the two rods were placed one in prolongation of the other the point of contact was formed by two steel edges meeting at right angles. A wooden bed with terminal stops of similar shape was made for verifying the length of the bars, the small interval between the end of the bar

* REINHERTZ, "Zeitschrift für Vermessungswesen," 1896, p. 7.

when laid on the bed and the bed-terminal being measured by means of a small steel wedge which admitted of readings being made to 0·01 millimetre.

This wooden bed on which the 5-metre fir rods were verified was made in the autumn of 1897, and its length was determined by the aid of the steel triple-metre which, as already mentioned, had been compared with the Board of Trade copy of the Standard Metre. The three bars of the triple-metre were placed on the "bed" in contact; then first No. 1 and then No. 2 were moved to the front in turn, thus giving a length equal to the five bars used; the difference between this and the end of the bed was measured with the steel wedge. By repeating this three times each bar of the triple-metre was used five times in the following manner:—

1st measurement	with	bars	1, 2, 3, 1, and 2
2nd	..	..	..	1, 2, 3, 2, and 3
3rd	,,	,,	,,	1, 2, 3, 1, and 3

It was necessary to employ this method, since the total length of the three bars of the triple-metre had been furnished in the certificate and not the length of each bar.

The length of the bed was verified in this manner before and after any base-measurement was carried out with the fir rods, and each rod was compared with the bed at the same time, as well as before and after each group of measurements whenever this was practicable.

In July, 1898, therefore, when the cadastral survey of Egypt was to be systematically taken in hand in order to furnish a basis for re-assessing the land-tax throughout the country, the only standards of length which were available were—

1. The 4-metre Brünner-Ibañez bar and the apparatus belonging to it:
2. A steel triple-metre verified at the Standards Office in London:
3. A divided metre scale of German silver verified at the Standards Office in London.

As the triangulation which was being used in the first half of 1898 to control the work of the Revenue Survey in Giza province was dependent on one or two bases measured with a steel band without any correction for temperature being applied, while the error of the steel band itself was unknown, it was necessary to re-measure one or two sides of the triangulation at once in order to see whether any improve-

ment of the triangulation was possible without delaying the detail-survey. For this purpose the 5-metre fir rods alone were available, and with them bases were measured at Badreshein and Matania in Giza province.* A 100-metre steel tape was obtained a little later for use in measuring such bases until a set of Jäderin wires could be supplied, for it seemed probable that time might be economized by its use; the detail-survey was proceeding rapidly, and the task of providing a reliable triangulation reconnoitred, observed, and computed, before the position of the points of the theodolite traverses could be calculated, compelled the utmost economy of time. Even though the measurement of a base in the Fayum was delayed to the last possible minute, the Jäderin wires had not been received, and, in August, 1900, it was necessary to measure a base at once in order to compute the triangulation of the Fayum province, and the co-ordinates of the traverse points which were controlled by it.

It was then the hottest season of the year, and only two of the inspectorate were available for the work, so that after some deliberation it was decided that, under the circumstances, better results would be obtained by employing the 100-metre steel tape instead of the fir rods, and that time would likewise be saved. Since its length had not been determined by comparison with a recognized standard in Europe, it was necessary to verify the tape by means of the 5-metre fir rods. The wooden bed was verified six times as before with the steel triple-metre and its length at 0° C. was found to be 5·01092 metres; the lengths of two rods which were employed were then found to be 5·00404 and 5·00408 metres respectively at 0° C.

For the comparison of the steel tape with the fir rods, a 100-metre line was laid down on a level length of asphalt, on the side of the road alongside the offices of the Survey Department, 25-metre intervals being marked by lines engraved on brass plates which were affixed to stout wooden pickets sunk deeply into the ground. Ten measurements of this 100-metre length were made with the fir rods and the length of the tape was found to be 100·0411 metres at 16°·7 C. when strained to a tension of 12 kilogrammes, or 100·0346 metres under no tension.

This steel tape was subsequently used to measure bases at Tema in the province of Assiut and at Addendan and Dakka in Nubia for the

* See Chapter XI.

third order triangulation, and at Khattara, 12 kilometres north of Aswan; these last three were for controlling a length of triangulation over a narrow valley where the sides are all of short length.* It was also employed in the Eastern Desert to measure short bases at Muqsam, Um Harba and Muelih for the topographical survey of that part.

In May 1903 the 100-metre steel tape was compared with the 50-metre Jäderin steel wire No. 2. The tape and wire were each laid flat on the asphalt base at Giza and compared at tensions of 15 kilogrammes for the wire and 7 kilogrammes for the tape, and apparently at a temperature of 14° C., but the actual temperature is immaterial, if it is assumed that both wire and tape acquired the same temperature, and if their coefficients of thermal expansion are the same.

The tape at 7 kilogrammes tension and 14° C. was found to be equal in length to twice the wire at the same temperature and 15 kilogrammes tension less 0·0535 metres, when laid flat.

The length of the wire No. 2, that is the chord of the arc, was determined at Stockholm to be 50·0340 metres at a tension of 15 kilogrammes and temperature 14° C. The arc is longer than the chord by $\frac{L\ V^2}{24\ T^2}$ where L is the length of the wire, V its weight (exclusive of fittings at the ends) and T is the tension. V was found to be 0·909 kilogrammes by measurement of the cross-section and on the assumption that the density is 7·99. Hence the difference between the arc and the chord was calculated to be:

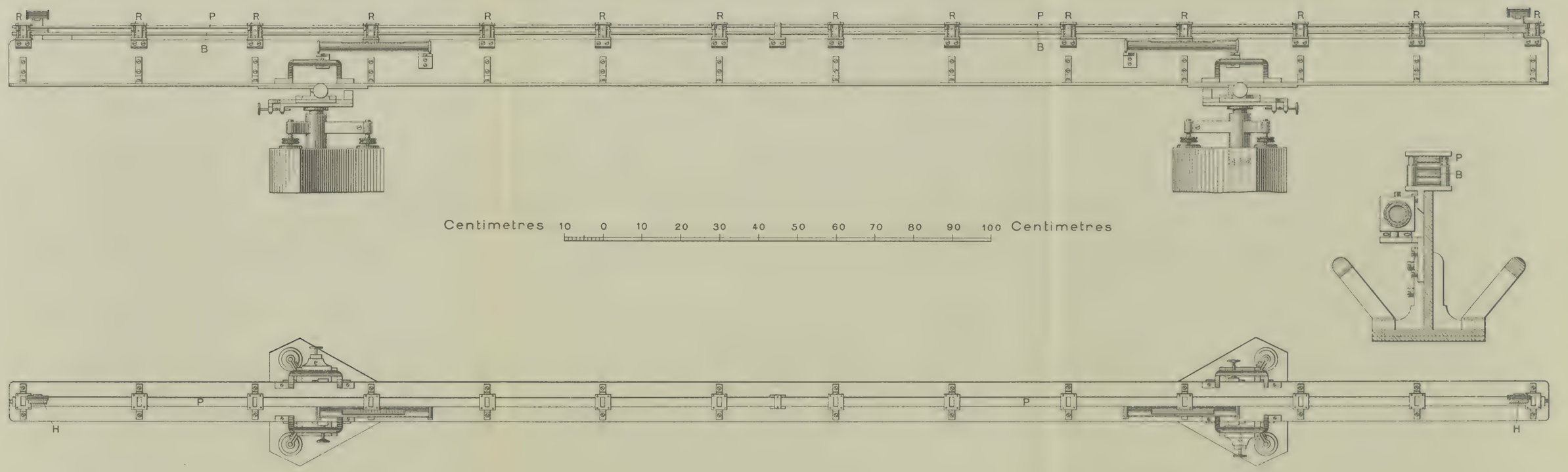
$$\frac{50{\cdot}03 \times 0{\cdot}909^2}{24 \times 15^2} \text{ or } 0{\cdot}00765 \text{ m.}$$

We have then:

		m.
Wire (2) at 15 kilogrammes and 14° C.	=	50·0340
Difference between the arc and the chord	=	+ 0·00765
Arc of the wire as above...		50·04165
Twice this	=	100·0833
Subtract the excess of twice the wire over the tape... ...	=	− 0·0535
Length of the tape at 7 kilogrammes tension and 14° C. ...		100·0298
Correction to 16°·7 C.		+ 0·0030
Length of the tape at 7 kilogrammes and 16°·7 C.	=	100·0328
Correction to length under no tension		− 0·0037
Tape under no tension and at 16°·7 C....		100·0291

* Plan XXIII.

THE FOUR-METRE BRÜNNER-IBANEZ BAR.



Survey Dept. Cairo, 1908. (358-85)

The length of the tape employed in the computations for the bases at Tema, Khattara, Dakka and Addendan and for the three bases of the Eastern Desert triangulation, as well as for some of the bases of the smaller town triangulations, was: 100·0291 metres. The length according to the determinations made at Helwan Observatory at the same temperature and tension, were as follows:—

November, 1905	100·0156 metres.
December, 1907	100·0151 „
June, 1908	100·0191 „

Under the conditions of carrying on work at high pressure which continued to prevail, it was seldom possible to measure bases at the most suitable time of year, for the intervals of time which could be allowed between the selection of a base and the computation of the triangulation which depended on it was often short. The use of a steel tape on heated ground was not desirable, and measurement by night was not convenient, so a set of Jäderin wires, with the necessary apparatus for using them for base-measurement, was ordered early in 1900 from the firm of F. J. Berg, of Stockholm, and was received by the end of the year. They had been standardized on the base laid out at the Polytechnic School at Stockholm and the following information was furnished concerning them:—

No. of wire.	Material.	Stockholm Experiments.		
		Temperature °C.	Tension kilogs.	Length metres.
1	Steel	12·4	10	25·0121
2	Steel	14·0	15	50·0340
3	Brass... ...	11·9	15	50·0315
4	Brass... ...	12·3	10	25·0105

This apparatus consists essentially of long wires to the ends of which short scales are fixed. The wires are strained under a constant tension by suitable means; a series of tripods carrying reference marks is placed at equal distances in a straight line along the base, and the distance between consecutive reference marks is measured by means

of the wires. Two wires, both being of 25 or 50 metres in length, were to be used simultaneously, one being of steel and the other of brass; they thus formed a bi-metallic and hence temperature-compensated standard.

One of the 50-metre wires was accidentally broken while measuring a base near Roda in Minia province, so that only the 25-metre wires could be used afterwards. The reference marks were at first pin-points clamped in the tripod heads and the alignments were laid out with a theodolite; the difference in level between successive tripods was found by spirit-levelling in the ordinary way. As soon as the new apparatus designed by MM. Benoit and Guillaume was received in December 1905, it was used instead of the old Swedish apparatus from that time onwards.

When the 4-metre bar had been received from Paris and the Comparator House had been built at Helwan, it was possible to re-determine the lengths of these 25-metre wires, and the following results were obtained by Mr. B. F. E. Keeling in February, 1908:—

Wire No. 1	Steel	25·01235	at 20°·8 C.
Wire No. 4	Brass	25·01308	at 20°·8 C.

Reducing these values to 12°·4 and 12°·3, the temperatures of the Stockholm experiments, we find, assuming $1 \cdot 0 \times 10^{-6}$ and $1 \cdot 75 \times 10^{-6}$ per 1°C as the coefficients of steel and brass respectively:—

Wire No. 1	25·01025	at 12·4
Wire No. 4	25·00936	at 12·3

Comparing these with the values obtained in Sweden in 1900 we find that in eight years:—

Wire No. 1 has shortened by 1·8 mm. or 1 part in 14,000
Wire No. 4 „ „ „ 1·1 mm. or 1 „ „ 23,000

Thus it would seem that a change has taken place in the length of the 25-metre wires between the time that they were used on the base at Stockholm in 1900 and their last verification at Helwan Observatory in 1908.

This change in length is in accordance with the experience of the Geodetic Survey of South Africa when using similar wires.* Comparing their lengths before and after measuring the first base with the

* British Association Report, 1905, page 237: "Origin and Progress of Geodetic Survey in South Africa." SIR DAVID GILL, K.C.B., F.R.S.

Comparator Houses at Helwan Observatory.

wires, Gill found that three steel wires had shortened by 1·3, 1·0, and 0·2 millimetres respectively. Three brass wires altered by 0·6, 0·5, and 0·1 millimetre. After two base-lines had been measured and three years after the original standardization, it was found that the total shortening was 1·8, 0·9, 0·6, 0·6, 0·9, and 0·3 millimetres. The magnitude of these quantities is very similar to the magnitude of the contraction of the wires of the Egyptian Survey. On page 162 of this report it is shown that there is considerable evidence to show that the Egyptian wires have not altered much since the Feshn base was measured in 1904. If this is so, all the modern bases of the Delta are self-consistent, though their absolute values require correction.

The following account of the last determination made at Helwan Observatory is furnished by Mr. B. F. E. Keeling, who, with Mr. P. A. Curry, carried out the work.

It will be noticed that the values for the first three stages of the work comprise but a limited number of observations. In fact they include the first series of what will be an extended standardization of the 4-metre bar and the 24-metre wires. The work as it now stands is, however, of more than sufficient accuracy for a second order triangulation. A complete account of the standardization work will be published as a part of the first report of the geodetic triangulation, which is now in progress.

The work of calibrating the 25-metre Jäderin wires, No. 1 (steel) and No. 4 (brass) was divided into five operations :—

(1) Comparison of Brünner-Ibañez 4-metre bar with "invar" sub-standard bar 4 metres in length ;
(2) Comparison of invar 4-metre bar with 24-metre base ;
(3) Comparison of 24-metre base with invar wire ;
(4) Comparison of invar wire with 600-metre base ;
(5) Comparison of 600-metre base with the 25-metre wires.

The particulars of each series of measurements and a general summary are given in the following pages, the symbols used being :—

m=metre,
mm=0·001 metre,
μ=0·000001 metre,
W_1, W_2 etc.=length of wire No. 1, No. 2 etc.,
t=temperature on "verre dur" scale.

(1) *Comparison of Brünner-Ibañez bar with the 4-metre invar bar.*

This was done in the 4-metre comparator; * the observers changed ends in the middle of each experiment.

			t°	L invar 4 m +
Scale A : †	Feb.	29, 1908	17·71	84·8
	March	1	17·67	85·4
	March	1	17·74	82·5
			17·71	84·2 μ ± 0·6 μ
Scale B : †	March	3	17·68	122·2
	March	3	17·76	121·0
	March	3	17·69	122·3
			17·71	121·8 μ ± 0·4 μ

Thus the mean of scales *A* and *B* at 17°·71 is

4 metres + 103·0 μ ± 0·4 μ.

(2) *Measurement of 24-metre base‡ with the 4-metre invar bar.*

Each section was measured as follows :—

Using scale *A* on invar bar :—

1. With micrometers face right and observers *X* to left and *Y* to right.
2. " " " " observers reversed.
3. " " " left, observer *X* to right and *Y* to left.
4. " " " " observers reversed.

Using scale *B* on the invar bar measurements as above :—

The base was measured first from right to left, and secondly from left to right. The results were as follows :—

I. Base = 6 × bar + 1030 μ at 16°·73.
II. = 6 × bar + 991 μ at 18°·85.
Mean = 6 × bar + 1010 μ at 17°·79.

---

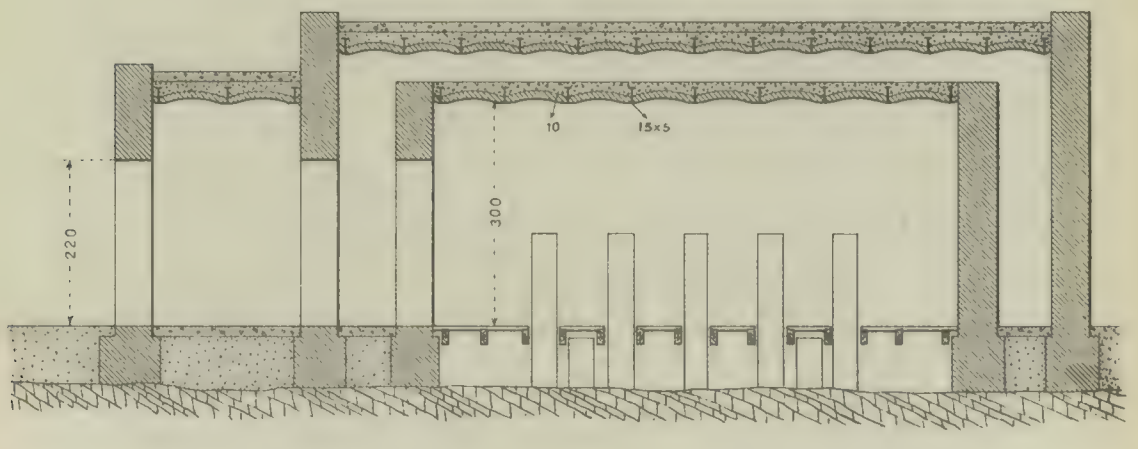
* See p. 167.

† Scale A is on the top of the invar bar and scale B is on the front of it; Plate. IX.

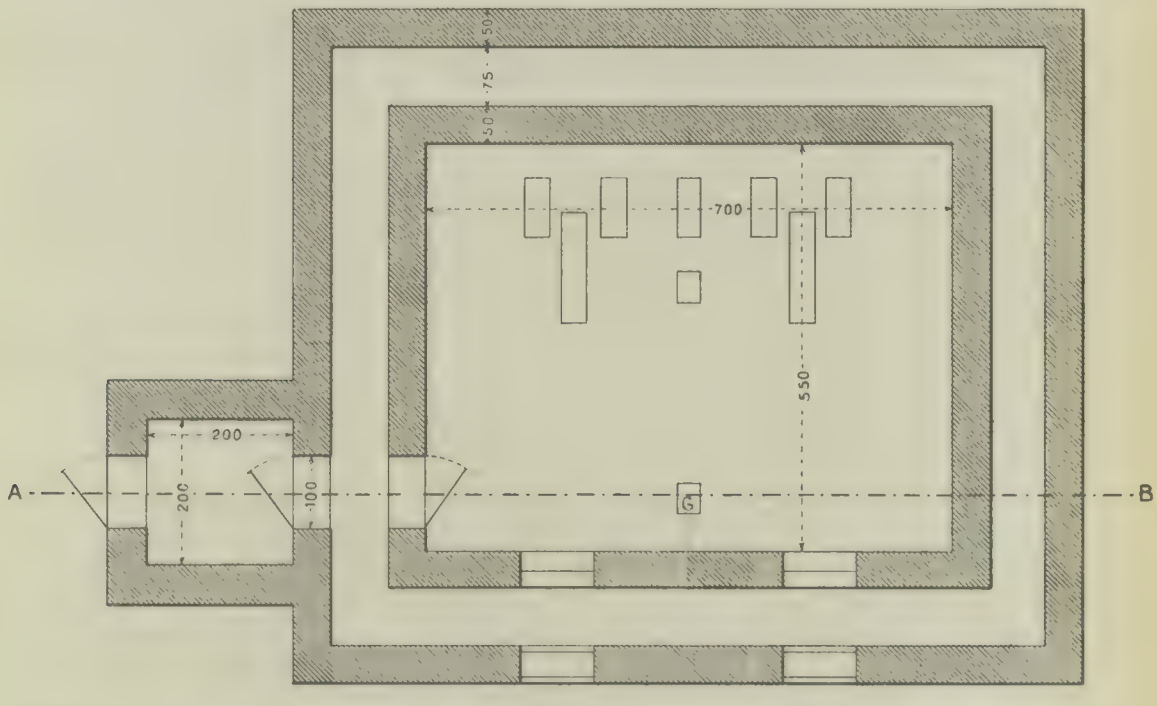
‡ For a description of this base see pp. 160, 172.

PLAN AND SECTION OF THE FOUR-METRE COMPARATOR HOUSE.

Cross section on A–B



Plan



NOTE

All dimensions in cm.

Scale 1 : 100

Survey Dept. Cairo 1908 (356 851)

The two measurements give the very reasonable value :—

$$\frac{39}{2{\cdot}1 \times 24} \times 10^{-6} = 0{\cdot}8 \times 10^{-6} \text{ per degree centigrade}^{*}$$

for the temperature coefficient of the invar bar, but the close agreement of the mean temperature (17°·79) with that in the 4-metre comparator (17°·71) practically obviates the necessity of using a coefficient.

(3) *Comparison of 24-metre base with 24-metre invar wire No. 70.*

Date.		Temperature.	Base—Wire.	Reduced to 15°·5 C.
		°C	mm.	mm.
January	7	16·9	+ 1·035	1·066
	7	17·3	1·057	1·090
	10	17·4	0·968	1·011
	11	17·2	1·015	1·053
	11	17·3	0·975	1·015
	12	17·1	0·995	1·031
	13	15·6	1·005	1·007
	14	16·0	1·038	1·049
	19	12·7	1·085	1·022
	20	12·5	1·108	1·041
	22	12·7	1·080	1·017
February	4	15·9	0·968	0·977
	10	13·2	1·072	1·020
	15	11·8	1·100	1·022
	19	15·2	1·032	1·025
March	11	19·4	0·900	0·987
	Mean	15·5	1·027	1·027

The last column is deduced by using the coefficient obtained on the following page, namely :—

$$\frac{5{\cdot}62}{6} = 0{\cdot}94 \times 10^{-6}$$

From these results the value of the length of invar wire No. 70 may be taken as :—

$$W_{70} \text{ at } 15^{\circ}{\cdot}5 = \text{base} - 1{\cdot}027 \text{ mm.}$$

and as being correct to about 1 part in 1,000,000.

* Subsequent experiments show that the coefficient of expansion is $1{\cdot}22 \times 10^{-6}$ per degree centigrade.

(4) *The comparison of 24-metre invar wire No. 70 with 600-metre base laid out on the limestone desert east of Helwan Observatory.*

Date.	Temperature.	Base $= 25 \times W_{70} + 330$ mm	Computed.
1908		mm.	mm.
	C°		
January 20...	7·9	+ 16·86	15·48
20...	12·0	12·01	13·18
8...	16·8	10·73	10·48
February 2...	21·5	5·88	7·84
January 8...	22·0	7·64	7·56
February 2...	23·5	6·71	6·71
January 8...	27·4	4·82	4·50
January 8...	27·5	5·60	4·47

Combining the observations by least squares, we find that the length of the base $= 25 \times W_{70} + 330$ mm. $+ 19{\cdot}92$ mm. $- 0{\cdot}562\ t$ mm., and the right-hand column gives the values computed with this formula.

This gives $\frac{0{\cdot}562}{6 \times 10^5}$ or $0{\cdot}94 \times 10^{-6}$ as the coefficient of expansion of the invar wire No. 70.

The probable error of a single measurement is :—

$$r = 0{\cdot}67 \sqrt{\frac{8{\cdot}55}{8-2}}$$

$$= 0{\cdot}8 \text{ mm.}$$

and we may take the probable error of a value deduced from the formula and near the middle of the range as about :—

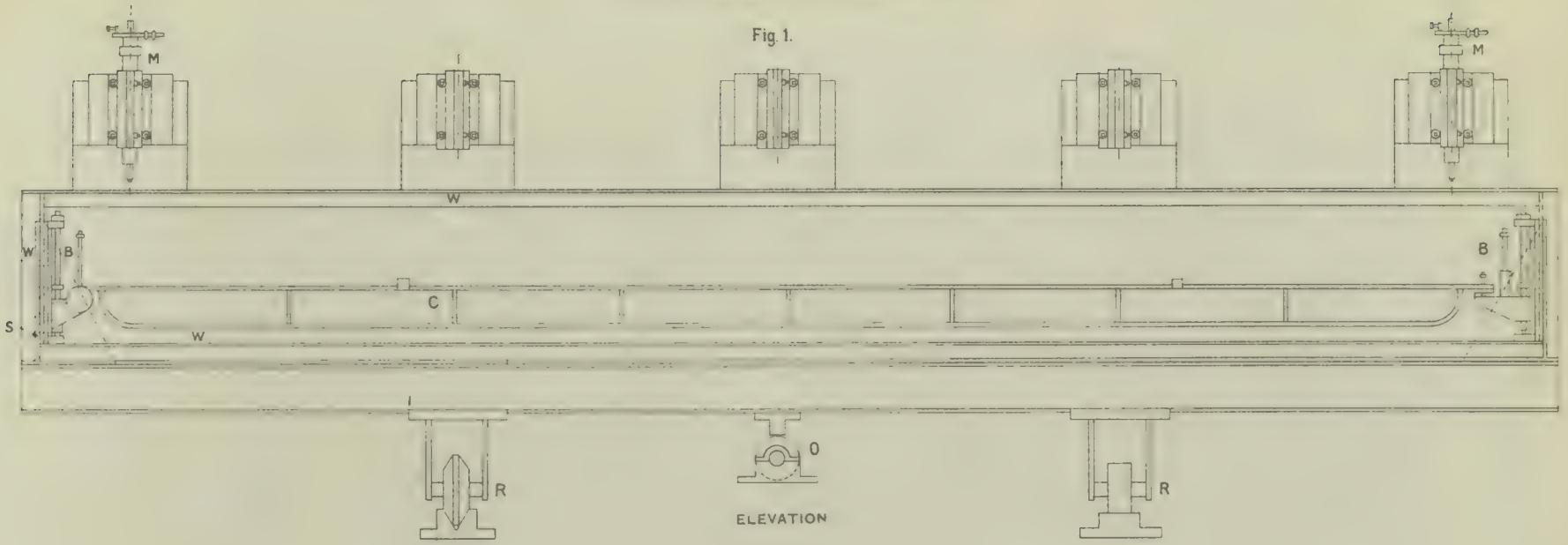
0·5 mm. or say 1 in 1,000,000

(5) *The comparison of the 600-metre base at Helwan with the 25-metre wires Nos. 1 and 4 on March 11, 1908.*

	Temperature.	Length of Base Line =	
		$24 \times W_1 +$	$24 \times W_4 +$
	°C	mm.	mm.
Measurement I	19·1	70·16	59·29
Measurement II	22·6	49·50	25·61
Means...	20·8	59·83	42·45

THE FOUR-METRE COMPARATOR.

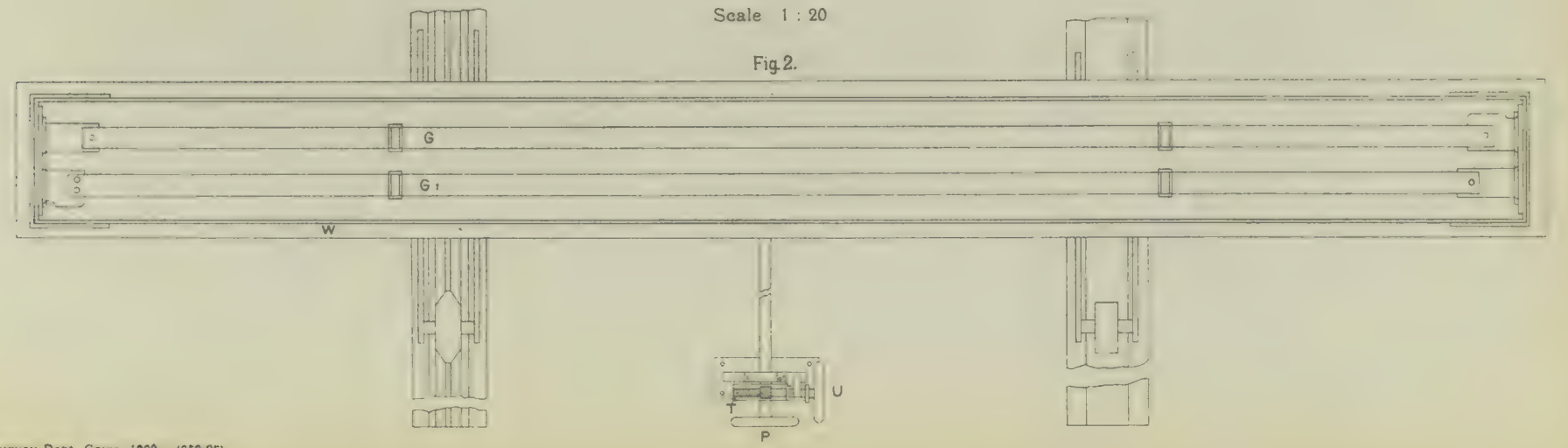
Fig. 1.



ELEVATION

Scale 1 : 20

Fig. 2.



PLAN

Survey Dept Cairo, 1908 (358-85)

The coefficients of expansion computed from the above figures are $1 \cdot 0 \times 10^{-5}$ for wire No. 1 (steel) and $1 \cdot 65 \times 10^{-5}$ for wire No. 4 (brass); the latter is considerably smaller than had been anticipated, but too much reliance should not be placed on these values owing to the small range of temperature.

Using the values formerly employed ($1 \cdot 0 \times 10^{-5}$ and $1 \cdot 75 \times 10^{-5}$), measurement II gives, when reduced to 19°·1, the following values :—

W_1 + 70·5 mm.
W_4 + 62·4 mm.

showing discrepancies between I and II of:

W_1 0·3 mm.
W_4 3·1 mm.

The mean value above is probably correct to 1 millimetre or about 1 in 600,000.

These results may be summarized as follows :—

I.— At 17°·71, Invar bar = 4 m. + 103·0 μ
∴ At 17°·79, Invar bar = 4 m. + 103·3 μ

II.— 24-metre base = 6 × Invar bar at 17°·79 + 1010 μ
= 24 m. + 618 μ + 1010 μ
= 24 m. + 1628 μ

III.— At 15°·5, Invar wire No. 70 = 24-metre base − 1027 μ
= 24 m. + 603 μ

IV.— With Invar wire at 15°·5,
600-metre base = 25 × W_{70} + 330 mm. + 19·92 mm. − 8·71 mm.
= 600 m. + 15·08 mm. + 330 mm. + 11·21 mm.
= 600 m. + 356·29 mm.
= 600·3563 metres.

V.— Wire No. 1 (steel):
600 m. + 356·29 mm. = 24 × W_1 at 20°·8 + 59·83 mm.
or W_1 at 20°·8 = 25 m. + 12·35 mm.
= 25·01235

Wire No. 4 (brass):
600 m. + 356·29 mm. = 24 W_4 at 20°·8 + 42·45 mm.
or W_4 at 20°·8 = 25 m. + 13·08 mm.
= 25·01308

The investigation of this change in the length of the wires has been undertaken, but it has been rendered more difficult since the first base measured with the wires is no longer available for remeasurement. The base at Feshn, in Beni Suef province, which was originally measured in November, 1904, has, however, been measured again in April, 1908, with the following results :—

	m.		mm.
Length of base from measurement in 1904 ...	2704·9060	±	10·2
" " " " " in 1908 ...	2704·9098	±	2·6

both measurements being computed with the old values of the constants for purposes of comparison ; it should be remembered, however, in comparing the two results that in 1908 the improved apparatus for straining the wires, aligning the tripods and reading off the scales, was available.

These two measurements were discussed as follows by Mr. T. L. Bennett :—*

" First, it should be remarked that, though two wires were employed, the lengths W_1 and W_4 of the wires only enter in the length of the base in the form:

$$\frac{1{\cdot}75\,W_1 - 1{\cdot}00\,W_4}{0{\cdot}75}$$

This expression may be called the 'length of the wires.'

" From the measurements of the base we find that the length of the wires had shortened by $\frac{3{\cdot}8}{108}$ † mm., or 0·035 mm., between 1904 and 1908.

" However, the probable error of this value 0·035 mm., is

$$\frac{\sqrt{(10{\cdot}2^2 + 2{\cdot}6^2)}}{108} \text{ mm.}$$

or 0.098 mm.

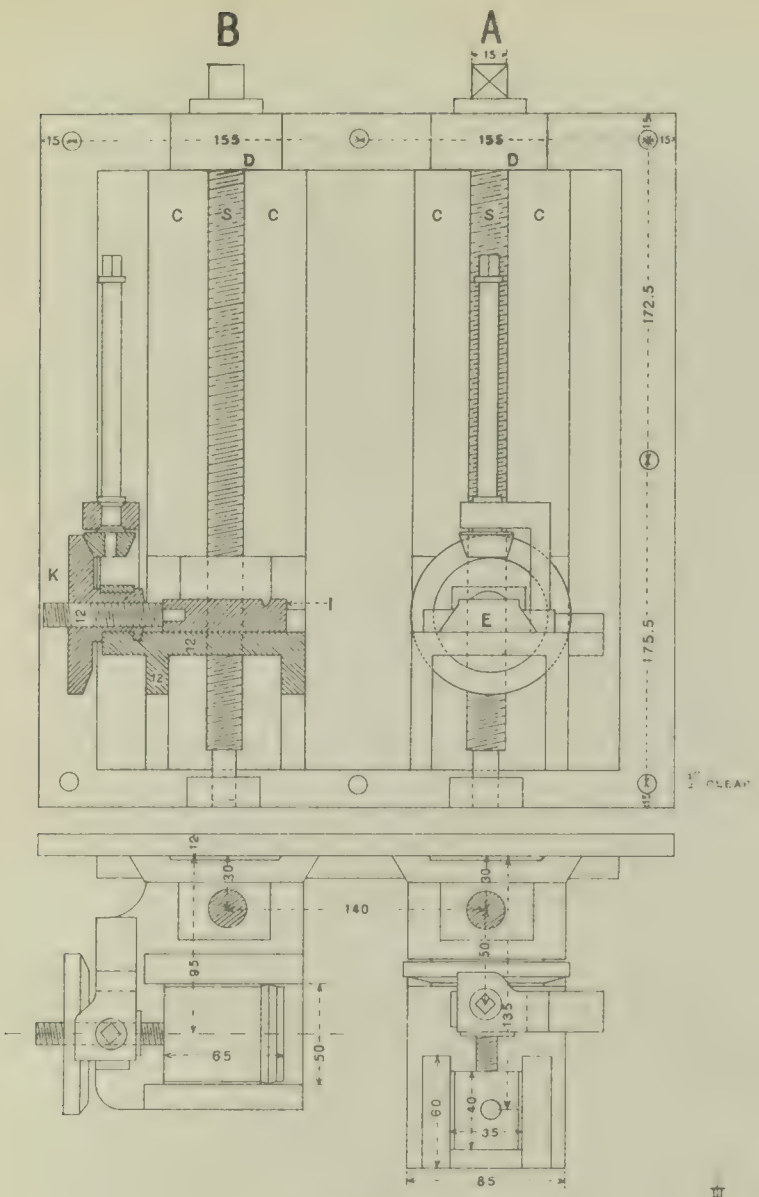
" Thus the odds are slightly in favour of the change in the wires being less than 0·035 + 0·098 mm., or 0·13 mm., (1 in 200,000). and it is practically certain that the change was less than 0·035 + 0·098 × 4 mm., or 0·43 mm., (1 in 60,000). "

" There is thus distinct evidence," Mr. Bennett concludes, " that these wires have altered but little in the three and a half years since

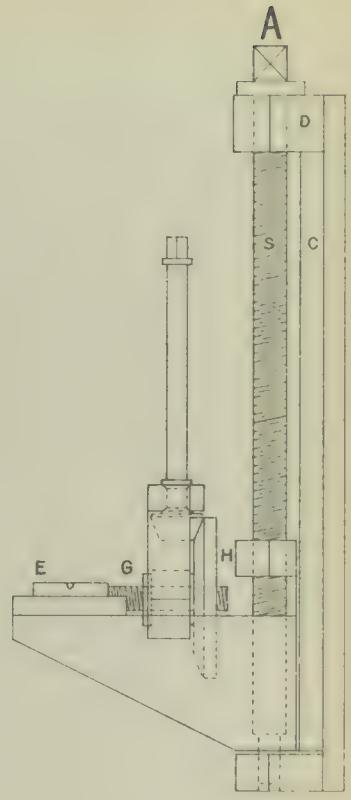
* Inspector in the Computation Office.

† The Feshn base included 108 wire-lengths.

DETAILS OF THE FOUR-METRE COMPARATOR.

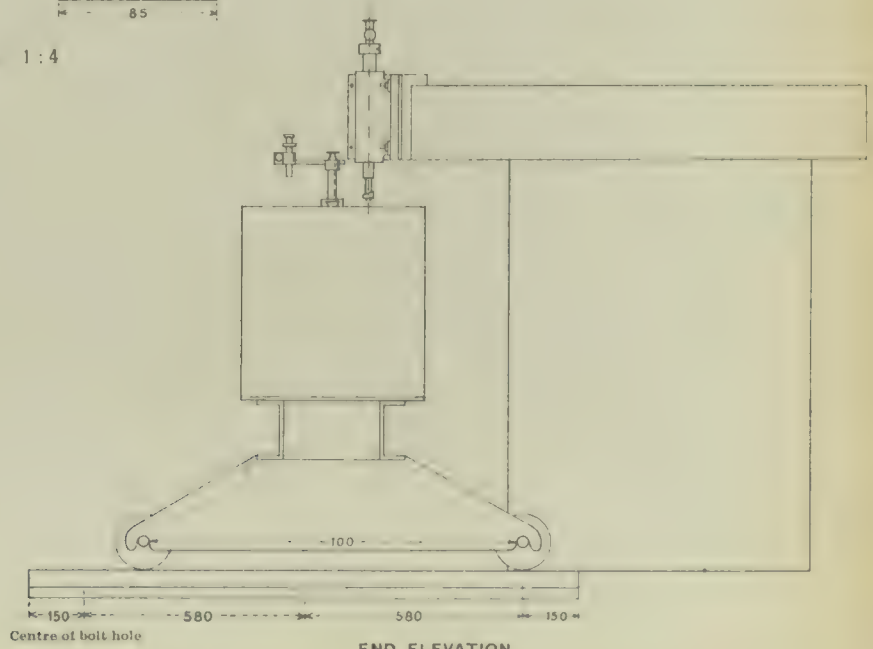


Scale 1 : 4



NOTE

All dimensions in mm.



END ELEVATION

Scale 1 : 20

Survey Dept. Cairo 1908 (356 85)

November, 1904, or if they have altered it is in such a way that the above expression remains nearly unchanged. "

It now remains to discuss the other bases in the same way; the Abbassia base could only be referred to by re-computing its length from the ones measured at Tel el Kebir, and Waqed, though this must be affected by any triangulation errors.

Another test is afforded by measurements of the 100-metre base at the Observatory made with the two 25-metre wires at three different dates :—

	Apparent temperature of wires.	Length.	Difference from mean.
		m.	m.
May, 1906	30°·1 C.	100·0128	−0·0019
August, 1907	29°·4 C.	100·0162	+0·0015
March, 1908	24°·6 C.	100·0150	+0·0003
Mean...	—	100·0147	—

so that it would appear that any alteration of the wires in length has been very small during this period.

Recently, wires made of invar, an alloy of nickel and steel having an extremely small coefficient of expansion, and consequently being particularly suitable for use under such conditions as exist in Egypt, have been procured, together with a new apparatus for using them in which many improvements have been introduced ; these wires, together with the method of using the apparatus, have been fully described by MM. Benoit and Guillaume.*

These new wires made of invar are 24 metres in length, to facilitate their being standardized by means of the 4-metre Brünner-Ibañez bar. Eight have been purchased and have been standardized on the 24-metre comparator at Helwan Observatory. Subsidiary wires of 8 metres and 4 metres and a 4-metre tape divided into centimetres form part of the equipment and are intended for use when the base-line is not a whole multiple of 24 metres. The wires are transported on a

* "Les nouveaux appareils pour la mesure rapide des bases géodésiques." Paris. 1906.

light metal drum, and when in use they are strained by 10-kilogramme weights attached to the wires by cords passing over pulleys mounted on ball-bearings. The edge of the scales at the ends of the wires lies in the neutral axis of the wire, and the reference marks consist of fine crosses engraved on the silvered tops of cylinders which are furnished with levelling screws and mounted on the tripods so as to form the fixed points at the end of each wire length. Small telescopes are provided for fixing on the tripods and are made so that the tripods can be aligned and the difference in level between successive tripods found without the necessity for using a theodolite or level. The speed of work is very much increased with a small accompanying increase in the number of men required.

The four-metre Standard Bar.*

The principal standard of length in Egypt is a four-metre compound bar which was purchased by the Khedive Ismail Pasha in 1863 and was described by Ismail Effendi Mustafa, afterwards Ismail Pasha el Falaki, in 1864 † (see Plate IV).

Said Pasha originally ordered the bar in 1858, and in 1861 he entrusted to Ismail Effendi Mustafa the study of the apparatus which had been ordered from Brünner of Paris. It is of the same type as the one belonging to the Geographical Service of the French Army and as a third which is owned by the Spanish Government. The method of using it has been described by Colonel Ibañez in his account of the measurement of the base at Madridejos,‡ and again by Koppe when the apparatus was borrowed by the Swiss Government in order to measure a base at Aarberg.§ The determinations of the coefficient of expansion of the bar, of the errors of its division, and of the divisions of the thermometers were made in 1862 and 1863 at Paris. The bar was compared with the one belonging to the Spanish Government in November, 1862, at Madrid, and its length

* There is no law which defines a special standard bar as the primary standard of length for Egypt. The Khedivial Decree of April 28, 1891, legalizes the metric system and gives the value of local weights and measures in terms of the metre and kilogramme. Cf. Chap. III, p. 41, App. IV.

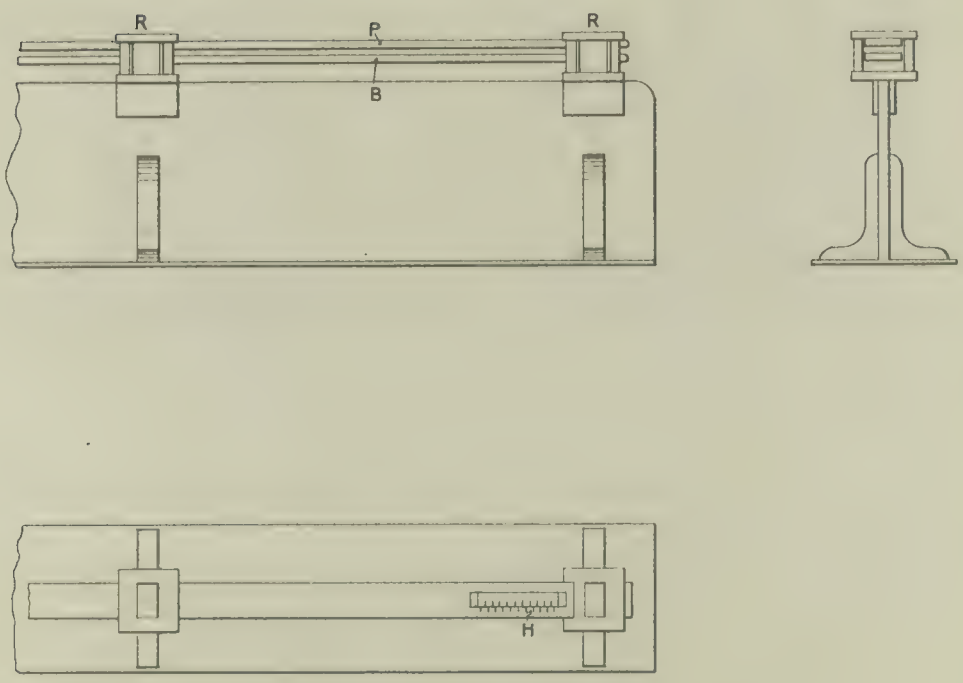
† "Recherche des coefficients de dilatation et étalonnage de l'appareil à mesurer les bases géodésiques appartenant au Gouvernement égyptien." Paris, 1864.

‡ "Base central de la Triangulation geodésica de España." Madrid, 1865.

§ Koppe (C.). Eisenbahn, Bd. XIV, Nr. 5, u. 8, Jan. 1881.

AN END OF THE FOUR-METRE BRÜNNER-IBANEZ BAR.

Fig. 1.



Survey Dept. Cairo, 1908 (358 85)

was determined in terms of the latter, which had been compared in 1856 with the platinum bar at Paris known as Borda No. 1.* Ismail Effendi Mustafa gives 4,000·5522 millimetres as the length of the platinum bar of the Egyptian apparatus at 12°·48 C., the length of the Borda No. 1 being taken, at 17°·6 C., as exactly equalling two toises, or 3,898·0732 millimetres.

The apparatus was sent to Egypt, where, according to Linant Pasha †, it was not even unpacked.

In 1876, Mr. (now Sir David) Gill laid out a base on the edge of the desert below and to the south-east of the Sphinx. Several of the masonry blocks, which were placed at four metres interval and in which metal bolts were placed, have been found again, but many are missing and almost all the bolts have been removed. So far as can now be ascertained, the observations were never worked out, nor was any attempt made to utilize the base in any system of triangulation. General Stone, of the Egyptian General Staff, is said to have measured a base on the road between Giza and the Pyramids a little later, but neither was this piece of work ever completed or utilized in any way.

In 1884 Colonel Ardagh, R.E., then quartered in Egypt with the Army of Occupation, urged that a topographical survey of the country should be made, and that the base apparatus should be examined and put in order. A sum of L.E. 1,000 was allotted to the Ministry of War in 1885, but only L.E. 70·076 was spent on repairs, etc., to the bar itself, and these were carried out at the Arsenal in Cairo. There is no record of anything else being done.

In 1897, when Colonel the Hon. M. G. Talbot, R.E., was sent to Egypt to carry out some surveying in the neighbourhood of Wadi Halfa and Suakin, he was instructed by Sir John Ardagh, then Director of Military Intelligence, to find out what had become of the Brünner-Ibañez apparatus. No use had been made of it between 1885 and 1897, and all traces of it had disappeared, but after some search it was found in a room at the Abbassia Observatory, where it had lain during the twelve years. No record existed which would show how it had

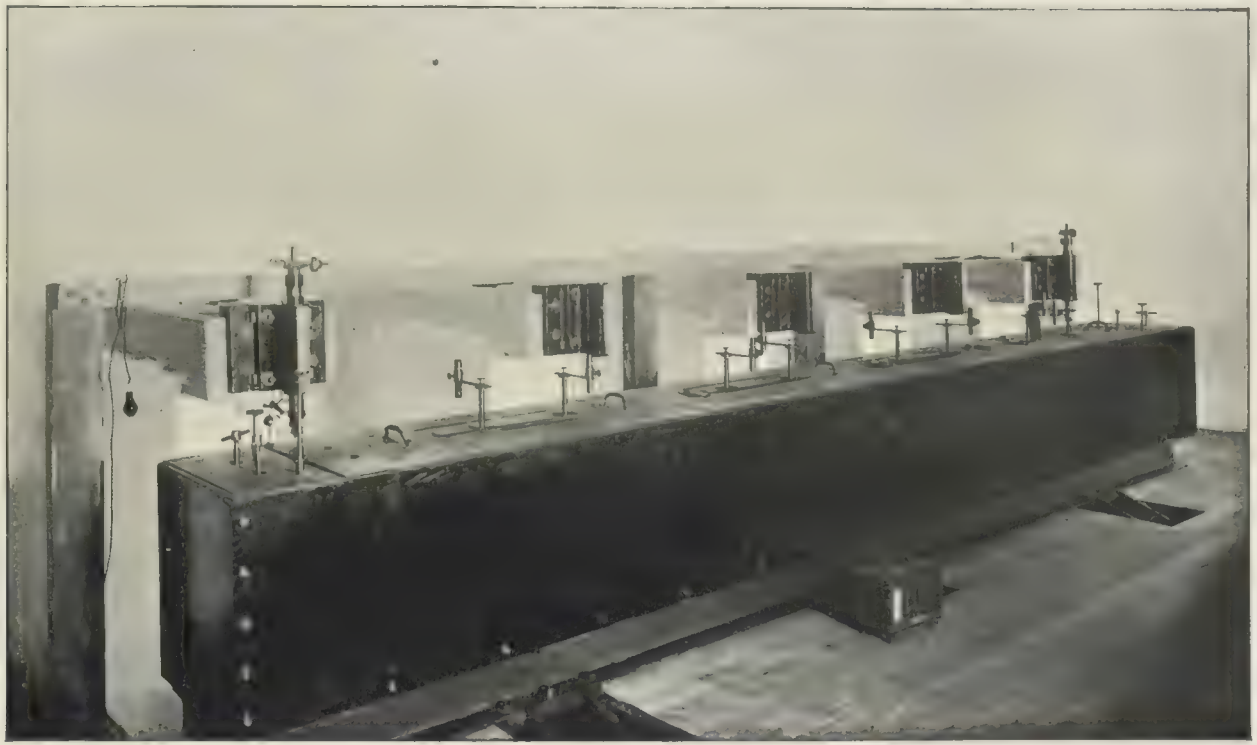
* "Expériences faites avec l'appareil à mesurer les bases appartenant à la commission de la Carte de l'Espagne."

† LINANT PASHA, "Mémoire sur les principaux travaux d'utilité publique exécutés en Egypte." p. 381.

been treated during the thirty years that it had been in Egypt, nor was the nature of the repairs made in 1885 known, and it was evidently inadvisable, in the absence of such information, to use the values obtained in 1862 without further verification. When examined, the bar proved to be in good condition, except that some of the engraved lines marking the divisions had been slightly damaged. It was decided, therefore, to send the bar to the firm of Gautier, in Paris, for cleaning and putting in order. The Turkish Empire was no longer a subscriber to the Bureau International des Poids et Mesures, which was established in 1874 at Breteuil, near Paris, for supplying national institutions with accurate standards of length and weight, but, at the suggestion of Sir George Darwin, K.C.B., F.R.S., application was made to M. Benoit, the Director, who most courteously undertook the work of re-determining the length of the bar, and its physical constants.

This work occupied many months, since it was desirable to work under as wide a range of temperature conditions as possible, at the same time it was deemed inadvisable to place the bar in a trough filled with a solution which might be artificially heated. The necessary comparisons were finally completed in 1904, and in the autumn of that year the bar was returned to Egypt, where it has been placed in a special double-walled house at Helwan Observatory (Plates V and VI).

It consists of two bars each 4·05 metres in length, one being of platinum P (Plate IV) and one of brass B, the two forming a bi-metallic standard. The bars are supported one above the other on a series of fourteen equally spaced pairs of rollers R, which are fixed to a deep ⊥ girder of iron 13 centimetres deep and 10 centimetres broad, fitted with fourteen stiffening gussets. Each bar is 21 mm. broad and 5 mm. thick. Each has a separate series of rollers which are 6 mm. apart. The platinum bar is the upper and is pierced near each end by an oblong hole H in which slide two pieces of brass fixed to the brass bar. Along one side of these openings where the two scales are thus brought into contact are the fine lines which form the reference marks of the standard. The outer end-divisions of the two scales are numbered respectively 0 and 100 and are approximately 4 metres apart, forming the terminations of the 4-metre standard of length. For six centimetres inside each of the terminal lines the edge of the opening is divided into tenths of millimetres and the whole



The 4-metre Comparator in position.

length of the platinum bar is divided into centimetres. The small brass pieces sliding in the openings of the platinum bar are similarly divided into tenths of millimetres. The rollers are very accurately adjusted so that no strain is placed on the bar.

The following is a summary of the final result of the comparisons made at the Bureau des Poids et Mesures, and a copy of the certificate is given in Appendix II :—

Coefficient of expansion of platinum	$8{\cdot}774 \times 10^{-6}t + 1{\cdot}70 \times 10^{-6}t^2$
,, ,, ,, of brass	$18{\cdot}067 \times 10^{-6}t + 6 \times 10^{-6}t^2$
Length of platinum scale at 0°C...	4,000·1058 mm.

The certificate shows the very complete nature of the tests to which the bar was subjected.

For obtaining the length of metallic wires and tapes in terms of this bar, there are now at Helwan Observatory :—

A 4-metre comparator in which the Brünner-Ibañez bar and the invar secondary standard can be placed for comparison ;
An invar 4-metre bar as a secondary standard ;
A 24-metre base in a special building 30 metres long ;
A 100-metre base out of doors ;
A 600-metre base laid out on the limestone desert to the east of the Helwan Observatory.

These means of obtaining accurately the length of base-lines in terms of the 4-metre standard bar will be shortly described.

4-Metre Comparator.

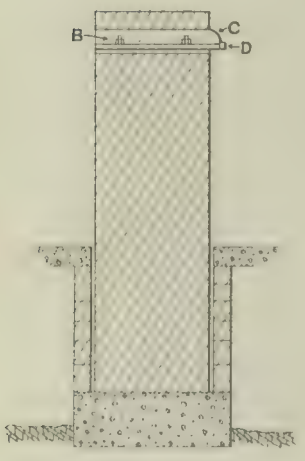
The design of the comparator has been regulated by several considerations. In the first place the Brünner bar has a considerable amount of steel fittings, including the axes of the rollers on which the scales rest. It is obviously inadvisable to place the bar in water, and after careful consideration M. Benoit was of opinion that it was dangerous to immerse it in a liquid at all. Accordingly all the comparisons made at Breteuil were conducted in air, the necessary range of temperature being obtained by working at different seasons of the year. The comparator at Helwan is therefore not a water-bath comparator, though it has been designed so that it could easily be converted into one at a trifling cost. Again, the great depth of the Brünner standard necessitated a deeper tank with greater range of the adjusting screws than is required for the comparison of more modern standards of length.

The instrument which is installed in the comparator house has been made by Messrs. Troughton and Simms, of London, from the designs of Mr. B. F. E. Keeling, who was kindly permitted by the Director of the National Physical Laboratory at Bushey Park, London, to use the drawings which he had made when there for a somewhat similar apparatus. A general view of the instrument is shown in Plate X and drawings are given in Plates VII and VIII. The bars to be compared are placed in a large tank which is made of copper about 1·5 mm. thick, and which is 40 centimetres wide, 45 centimetres deep and 450 centimetres long; it is covered by a lid also of sheet copper. This tank is covered on the outside with thick asbestos board, and outside that is two inches of Spanish mahogany, the lid being similarly covered on the under side. Each end of the tank is formed of a brass plate 1 centimetre thick which serves to support the adjustable brackets carrying the girders on which the standard bars rest. These girders are made of cast gun-metal in channel form and have several stiffening webs along the length of the girders. The upper flange is planed and surfaced to form a slide for the rollers supporting the scales, and for the supports for the thermometers.

Each girder is fitted with three levelling screws, one at one end resting in a conical hole on the supporting bracket at that end, and two at the other end, of which one rests in a V-shaped slot and the other on a plane surface on the supporting bracket. A detailed drawing of the supporting brackets is given in Plate VIII. In this figure A is the bracket on which the single screw end of one girder G (see Plate VII) rests, and B is the bracket on which the double screw-end of the second girder G' rests. The brackets move in vertical slides CC and are raised or lowered by the screws (of 2 mm. pitch) SS, the weight being taken by the bearings DD. On the bracket A slides a plate E in which is the conical hole above referred to. This plate can be moved through a range of about 2 centimetres by means of the screw G which is actuated by the bevel wheels H, the direction of motion being along the length of the tank. By similar means the plate I on which are the plane and the V-shaped slot can be moved by the screw and bevel wheels K at right angles to the length of the bar. At the other end of the tank the girder G rests on a plate similar to I and the other girder G' rests on one similar to E. With these brackets either of the girders may be raised or lowered at each end, and at the

PLAN OF THE 24-METRE COMPARATOR HOUSE.

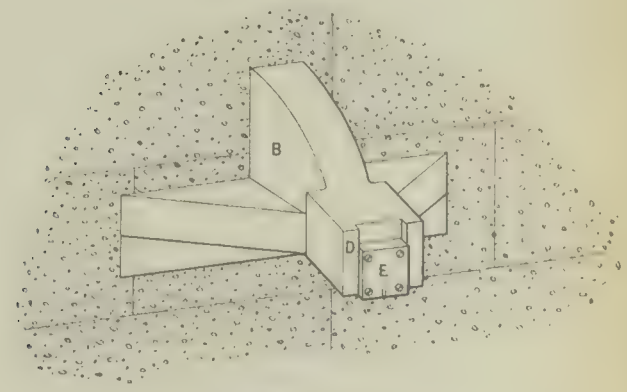
Fig. 2.



Scale 1 : 40

cms. 50 0 0.5 1 metre

Fig. 3.



Scale 1 : 4

mms. 50 25 0 0.5 10 cms.

Fig. 1.

Scale 1 : 200

cms. 200 100 0 2 4 6 metres

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same time may be moved slightly along the length of the girder by H, while the direction of the length may be slightly altered in azimuth by K.

The tank is supported on two 5-inch steel channel girders (Plate VII) and braced along its length by steel plates. The ends of the tank are stiffened and held rigid by the cast-iron brackets S, which are bolted to the channel girders, so that there is no tendency to crumple the tank. These girders rest on the cast-iron carriages R, the distance between the centres of the carriages being 3 metres. Each carriage runs on two wheels, the length of the wheel base being 1 metre; the wheels on the left-hand carriage are V-shaped with a 60° angle, those on the right-hand carriage being cylindrical, and the former run in corresponding V-shaped rails whilst the latter run on flat rails. Each wheel is attached to the carriages by motor ball-bearings placed at the outer ends of the wheel-axes. The rails being at right angles to the length of the tank, the latter can be moved transversely to its length. The tank is moved on the rails by means of a central rack geared with the worm-wheel O which is turned by the hand-wheel P at the end of the long shaft. One revolution of the hand-wheel, which is 12 inches in diameter, advances the tank 1 inch. A slow motion consisting of a worm-wheel T fixed to the shaft, and a worm driven by the hand-wheel U, which can be thrown in and out of gear by an eccentric, is also provided, so that micrometric motions can be given to the tank.

The two bars to be compared are supported on the girders G and G^1, placed at a suitable distance apart. The reference marks upon them are viewed by the vertical microscopes M, through sight-holes drilled through the lid. These microscopes, which are at present two in number, have been made by the "Société Genevoise pour la construction d'Instruments de Physique" according to the model recommended by the "Bureau International des Poids et Mesures"; and are arranged so that the distance from the object-glass to the object is about 11 centimetres, whilst the distance from the object-glass to the plane of the cross-hairs of the micrometer is 40 centimetres. Three pairs of movable cross-hairs with varying distances between the hairs are provided to allow for observing divisions of different coarseness on different bars. The magnification of the microscope is ordinarily about 80, though a pair of more powerful eye-pieces is provided. The pitch of the micrometer screw is such that one revolution corresponds to one-tenth of a millimetre on the object, and, as the micrometer drum is divided into

one hundred parts, microns (thousandths of a millimetre) are read directly, and tenths of microns by estimation. In the tube of the microscope immediately above the object-glass is placed a plate of thin specially chosen glass inclined at 45° to the line of collimation, by which light is reflected down on to the scale from a small 8-volt electric lamp.

The house in which the comparator is placed has been built of the local limestone and is double-valled, so that the temperature changes in the comparator room may be small. A plan and cross-section of the house is given on Plate VI. The walls are each 45 centimetres thick and are carried down to the solid rock, the footings being 55 centimetres thick. There is a porch on the east side so that there are three doors between the outside air and the comparator chamber. The inside walls are covered with white plaster of good quality to reduce the amount of dust, the walls in the air space being left rough. The floor of the porch and of the passage is of concrete faced with cement, the inner floor being of wood carried on joists hung from the walls. The roof, like the wall, is double, and is formed of brick jack arches supported on steel joists. Above the brickwork is a bed of rubbish, above this being 15 centimetres of lime concrete, the outer roof having in addition a layer of asphalt 2 centimetres thick, graded to three rain pipes which discharge on to the ground outside. In the north walls are two small windows, the outer ones being furnished with wooden shutters.

The microscopes of the comparator are carried by brick pillars which have been built up from the limestone rock and are 80 centimetres by 35 centimetres in cross-section, the footings below the floor being 25 centimetres larger. They are capped by single stones 125 centimetres long, 35 centimetres broad and 25 centimetres deep, which are cemented to the pillars so that they overhang equally at the two ends. The iron socket of the microscope is secured into the end of the stone next the comparator tank by rag-bolts set in cement. These sockets, which are very substantial, have small adjustments in all directions, so that they may be accurately levelled, aligned and spaced. Five sockets on a corresponding number of pillars are provided, with intervals of 1 metre between the centre lines of adjacent pillars.

The microscopes being fixed, the two bars to be compared can be brought into the field of view in succession by means of the traversing worm, and can be focussed and accurately aligned by the adjusting screws of the end brackets supporting them.

Interior View of the 24-metre Comparator House.

The temperature of the inside of the tank is determined by eight symmetrically placed thermometers, which are carried horizontally by wire forks attached to brass pieces sliding along the gun-metal girders G, G_1 so that they can be placed at the desired position. The lid is made in four overlapping sections so as to be easily removable, and the thermometers are viewed through good plate-glass windows in it two centimetres broad. Sliding along a central brass slide on the outside of the lid are the supports for the eight vertical microscopes by which the thermometers are read.

For use in the comparator ten thermometers have been purchased. They are made of XVI^{III} Jena glass. The thermometers are divided into tenths of degrees from 2° to + 52° C. Above the latter division is a small chamber and above this the degrees 98° to 102° are marked. In this way, without being of undue length, a thermometer is obtained which is sensitive over the particular range required, and has at the same time the advantage that its fundamental interval can at any time be determined. The thermometers have been compared by Dr. J. A. Harker at the National Physical Laboratory of England with the standard Baudin thermometers belonging to that institution, the fundamental points 0° C. and 100° C. being of course independently determined.

24-METRE COMPARATOR (Plates V, XI and XII).

This has been modelled on that in use at the "Bureau International des Poids et Mesures," but the hard nature of the rock made it impracticable to use an underground chamber such as exists at the Bureau and the comparator building is above ground. It is shown in plan in Plate XI. The building is of stone, and is twenty-eight metres long, five metres broad, and the height to the ceiling is three metres. It is entered by porches, each with two doors, placed at the ends. Light is obtained from a series of windows in the north wall. The roof is double, the outer one, which is sloping being covered on the outside with red tiles and on the inside with wood boards, so that there is a space of 15 centimetres between; the inner roof which forms the ceiling is of wood. The floor of the building is of concrete rendered with cement.

Inside the building are the reference marks of the comparator, which are shown in Plate XI. They are mounted on seven piers each 60 centi-

metres square, which are carried down to the rock and isolated from the floor by brick retaining-walls ; there is also an eighth pillar one metre distant from the seventh. The others are placed four metres from centre to centre and are built of brick set in cement which is carried up to 100 centimetres above the floor level. Securely bolted on to each pier are the heavy cast-iron brackets B which carry the reference marks. The brackets are T-shaped and project 10 centimetres outside the piers as shown at C. Screwed into a shallow groove on the outer vertical face D are small nickel plates (E, Fig. 3) four centimetres square, which are highly polished and carry two fine marks one millimetre apart which form the reference marks of the comparator. There are thus six four-metre distances along the length of the building with their ends defined by the marks on the nickel plates, forming in all a length of twenty-four metres, besides an additional metre to extend the length to twenty-five metres for use when standardizing the older Jäderin wires from Stockholm which are of this length.

A base 100 metres long for the comparison of 100-metre tapes has been installed at the Observatory outside the comparator houses.

Another base 600 metres long has also been laid down on the limestone desert to the east of the Observatory, and the length of this has been carefully determined by means of the invar wires to be 600·3563 metres as already stated on page 160.

Jäderin Wires in use in the Desert.

CHAPTER XII.

Base Measurements.

No portion of the survey has been more inconvenienced by the necessity for rapid execution of the work than the measurement of the base-lines. At first no satisfactory standard of length was available, so that a simple form of measuring apparatus had to be prepared for immediate use, then the 100-metre steel tape was obtained, and a year later two pairs of Jäderin wires made of brass and steel, the length of which had been determined at Stockholm, were received; finally, in 1906 the new pattern apparatus for using invar wires of the Jäderin type arrived, and was taken into use with the old wires until such time as the comparison between the 4-metre standard bar and the new invar wires had been carried out by the staff of the Observatory. Thus in this as in other branches of the work a gradual advance was made from more simple to more precise methods as rapidly as was practicable without checking the rate of work.

The narrow valley of the Nile is unsuitable for large triangles, so that the average length of the sides employed in the second order triangulation did not exceed 17 kilometres, and the increase of errors due to the angular measurements was most conveniently controlled by measuring short bases of from 2·5 to 3·5 kilometres in length at intervals of about 150 kilometres. Also as each province formed a group of villages of which the cadastral maps and land-registers had to be completed by a given date, it was convenient to have a base-line at or near the end of each province, so that the second order triangulation might be computed and adjusted with as little delay as possible. The result has been to increase the number of base-lines above what would have been used had not the rapid execution of the detailed measurements and the speedy production of the large-scale maps of successive provinces been of primary importance.

The following is a list of the base-lines which have been measured from 1898 to 1908 :—

Date.	Place.	Province.	Length in metres.	Base apparatus used.	Ultimate Standard.*
August, 1898 ...	Badreshein ...	Giza... ...	3,249	5-metre fir rods.	A
September, 1898	Matania.. ...	,, ...	2,629	,, ,,	A
August, 1900 ...	Seila	Fayum ...	2,902	100-metre steel tape.	A
June, 1901 ...	Moqattam ...	Qaliubia.	3,390	50-metre Jäderin wires.	B
April, 1902 ...	Gebelein ...	Qena.. ...	2,305	,, ,, ,,	B
April, 1902 ...	Ambir	Girga. ...	2,324	,, ,, ,,	B
May, 1903 ...	Tema	Assiut ...	2,800	100-metre steel tape.	B
October, 1903...	Addendan ...	Aswan ...	2,001	,, ,, ,,	B
December, 1903	Dakka	,, ...	2,699	,, ,, ,,	B
February, 1904	Khattara ...	,, ...	2,550	,, ,, ,,	B
April, 1904 ...	Roda	Minia ...	2,741	25-metre Jäderin wires.	B
November, 1904	Feshn	Beni Suef	2,705	,, ,, ,,	B
December, 1905	Tel el Kebir .	Sharqia .	2,105	,, ,, ,,	B
December, 1906	Waked... ...	Beheira .	3,528	,, ,, ,,	B
February, 1907	Ras el Khalig	Gharbia .	3,897	,, ,, ,,	B
August, 1907...	Halq el Gamal	Beheira .	3,268	,, ,, ,,	B

The first piece of work to be done when the Survey Department was formed in 1898 was to re-measure two sides of the triangulation of Giza province with such apparatus as was immediately available, since the co-ordinates of the points had been computed from a base measured in 1897 with a steel tape but no corrections had been applied to the results. This was done in August with the 5-metre fir rods which have already been described in the last chapter. Later on, as work developed and opportunity was afforded, improved methods were introduced to diminish, as far as possible, the uncertainty caused by the wide range of temperature which was often encountered in measuring base-lines on the desert, where the bases were always situated, since marks in the cultivated lands were very liable to be removed. In the following pages, details will be given of the various base-measuring operations which have taken place from August, 1898, when such work was first commenced, to 1908, after which year the improved Jäderin apparatus and the wires of invar, which have been compared with the Brünner-Ibañez bar will be exclusively employed.

* A. = Triple-metre standard see p. 150
B. = Jäderin 25-metre wires from Stockholm.

Badreshein Base.

In the summer of 1898, a base was measured between the triangulation points Nos. 186 and 191 in Giza province, on the railway just south of Badreshein station. The side of the triangle lay parallel to the western rail of the single line of railway which then existed, and two metres from it, so that the measurement was carried out between two points on the rail which were nearly opposite to the triangulation points, and the resulting length was then corrected to the triangulation points so as to give the total length between the two terminal points of the side. The 5-metre fir rods were verified on the bed, the length of which had been determined by comparison with the steel triple-metre, with the result that the length of the bed was found to be :—

Date.	Mean Temperature.	Length in metres.	Mean length in metres.
	° C.		
June 20-21, 1898	27·5 27·5	5·00949 5·00952	5·00950
August 5, 1898.	28·3 27·8	5·00928 5·00930	5·00929
End August, 1898... ...	28·0	5·00896	5·00896

The Badreshein base was measured on the 2nd and 3rd of August, 1898, the rods being compared with the bed before and after each measurement, with the following results :—

Date.	Hour.	Rod No. 1.	Rod No. 2.	Rod No. 1 + Rod No. 2.	30 lengths of 2 rods each.
		m.	m.	m.	m.
Aug. 2, 1898.	8.30 a.m.	5·00278	5·00203	10·00481	300·1428
	noon.	5·00273	5·00199	10·00472	
	3.15 p.m.	5·00259	5·00214	10·00473	300·1233
	7.0 p.m.	5·00200	5·00150	10·00350	
Aug. 3, 1898.	6.15 a.m.	5·00238	5·00146	10·00384	300·1074
	11.20 a.m.	5·00203	5·00130	10·00333	300·1095
	4.45 p.m.	5·00245	5·00152	10·00397	

The base was divided into eleven sections, of which numbers one to ten each contained about 300 metres or 60 rod-lengths, while the last equalled 49 rod-lengths; the measurements were made in the forenoon, and again in the afternoon in the reverse direction on the second day, so that, during the two days, the base was measured three times from north to south, and once from south to north. The results are given in the following table :—

BADRESHEIN BASE.

From triangulation point No. 186 to point No. 191; measured August 2-3, 1898.

Portion.	1st measurement N.—S.	2nd measurement N.—S.	3rd measurement N.—S.	4th measurement S.—N.	Mean.
	m.	m.	m.	m.	m.
1	300·1432	·1150	·1120	·1089	300·1198
2	300·1432	·1177	·1148	·1076	300·1208
3	300·1432	·1147	·1149	·1027	300·1189
4	300·1432	·1277	·1233	·1143	300·1271
5	300·1432	·1284	·1214	·1083	300·1253
6	300·1432	·1290	·1241	·1150	300·1278
7	300·1432	·1347	·1248	·1207	300·1309
8	300·1432	·1362	·1218	·1219	300·1308
9	300·1432	·1392	·1220	·1203	300·1312
10	300·1432	·1412	·1188	·1169	300·1300
11	245·1197	·1172	·1009	·0960	245·1084
Total...	3,246·5517	·4010	·2988	·2326	3,246·3710

Correction to extend base from north mark on rail to triangulation point No. 186 at north end...	+ 0·0070
Correction to extend base from south mark on rail to triangulation point No. 191 at south end...	+ 2.2742
Total length of side 186-191 in metres	3,248·6522

Probable error ± 15·0 millimetres.

The sections were laid down on the rail during the first measurement, by scribing a line on the rail surface at the end of each section, and these marked points were measured to at each subsequent measurement. In order to utilize the results at once, it was necessary to carry out the work during the hottest time of the year, and the bed for

verifying the rods had to be kept in the shade in a house ; consequently, the rods had to be carried back for verification after use, which explains three out of four measurements being made in the same direction. The rods were laid in position by Egyptian chainmen, after they had had some preliminary training in the work, and the measuring was superintended and recorded by an English inspector.

Matania Base.

A second base was measured a month later at Matania, about 32 kilometres further south, on September 1, 1898, between triangulation point No. 1 and point No. 2. The 5-metre rods were used, and the measurements were carried out in the same manner, but, the length being less, it was possible to complete one measurement in each direction in the forenoon, and another pair in the afternoon ; the first two were made between 10 a.m. and 12.45 p.m., and the others between 2.28 p.m. and 4.45 p.m. The rods were verified before and after work at 5·30 a.m., when the temperature was 21° C., at 1 p.m. when it was 35° C., and again at 2.15 p.m. and at 8.30 p.m. when it was respectively 35°·5 C. and 26° C.

The rod-lengths at the different times were : *—

Date.	Time.	Rod. No. 1.	Rod. No. 2.	Rods No. 1 + No. 2.
		m.	m.	m.
Sept. 1, 1898 ...	5.30 a.m.	5·00276	5·00185	10·00461
	1. 0 p.m.	5·00185	5·00102	10·00287
	2.15 „	5·00216	5·00131	10·00347
	8.30 „	5·00245	5·00172	10·00417

The same procedure was followed in measuring as at Badreshein. Thirty lengths of the two rods were marked off on the rail at the first measurement in the early morning and then the distances between these marks were re-measured three times, the mean of the four measurements being taken, when corrected for temperature, as being the true length of the section.

* The pair of rods used was probably not that used at Badreshein, but no definite record on this point exists.

The results of the four measurements are given in the following table in metres :—

Section.	1st measurement N.—S.	2nd measurement S.—N.	3rd measurement N.—S.	4th measurement S.—N.	Mean.
	m.	m.	m.	m.	m.
1 ...	300·1257	·0823	·0968	·1195	300·1061
2 ...	300·1257	·0925	1074	·1298	300·1138
3 ...	300·1257	·0983	·1147	·1319	300·1176
4 ...	300·1257	·0987	·1072	·1295	300·1153
5 ...	300·1257	·1003	·1142	·1321	300·1181
6 ...	300·1257	·1023	·1146	·1294	300·1180
7 ...	300·1257	·1104	·1167	·1272	300·1200
8 ...	300·1257	·1057	·1197	·1240	300·1188
9 ...	225 0943	·0742	·0878	·0963	225·0881
Total...	2,626·0999	2,625·8647	2,625·9791	2,626·1197	2,626·0158
Correction to extend base from north mark on rail to triangulation point at north end...					+ ·0289
Correction to extend base from south mark on rail to triangulation point at south end...					+ 2·7547
Total length of side No. 1 — No. 2					2,628·7994

Probable error ± 14·0 millimetres.

The lengths of the sides 1–2 near Matania and 186–191 near Badreshein differed largely from the values obtained previously by a single measurement with the steel tape when uncorrected for error, temperature and tension :—

Base.	Steel tape.	Fir rods.	Difference.
	m.	m.	m.
Badreshein	3,249·87	3,248·6522	1·22
Matania	2,629·05	2,628·7994	0·25

The first computation of the triangulation had been based on the measurements made with the steel tape, and the traverse lines of a certain number of villages had been adjusted in May, 1898, to triangulation points so determined. The values given by measurement with rods were certainly more accurate, and, therefore a new computation of the traverse lines was carried out in all villages where the detail-

survey had not been actually begun. Each village being at this time traversed separately, the triangulation points were only used to check the traverse work, and not to lay down the sheet lines of maps, since these were also prepared in groups each of which contained the lands of a single village.

Seila Base.

The next province to be triangulated was the Fayum, and therefore a base was measured at Seila, on the desert to the east of the Fayum, on the 10th, 11th and 12th of August, 1900, with the 100-metre steel tape which had previously been compared with the steel triple-metre by means of the 5-metre fir rods. The measurement had been postponed as long as possible in the hope that the Jäderin wires, which had been ordered from Sweden, would arrive in time to be used, but by August the length of the base was urgently needed by the Computation Office, and its determination had to be undertaken at once. The selected base, which was about 2,900 metres in length, was divided into four portions, three being 700 metres, and the fourth 800 metres in length; and stout wooden pickets were driven into the ground at intervals of a tape-length apart. On the head of each picket was nailed a plate of zinc, with fine cross lines ruled on it the intersection of which marked the point to which the measurement was to be made. The base was levelled on August 10, 1900, and the measurements occupied the two following days, one being made at dawn before the sun rose, and the other after sunset, since the sandy desert became so intensely heated by the sun's rays during the daytime as to render it inadvisable to measure between sunrise and sunset. The air temperature was determined for each tape-length by sling thermometers used at each end of the tape. The tape was laid on blocks of wood of triangular section, in order to reduce friction as much as possible, so that it rested on the wooden edges of the blocks, and for only about two-thirds of its length on the surface of

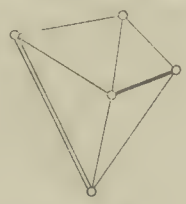

Fig. 2.

Seila base extension.*

Scale 1 : 300,000

* The thick line in the base extension diagrams indicates the base, and the double line a side of the second order triangulation network.

the desert; it was strained to 12 kilogrammes by means of a spring balance during the first two measurements, and to 15 kilogrammes during the last two. Uniformity of tension was secured by having the tape raised clear of the ground just before the measurement by three chainmen at equal intervals, who then lowered it gently into position. In subsequent measurements with the tape it was swung freely over rollers or on hooks hanging from wooden pickets. After the measurement, experiments were made at Giza to ascertain the effect of sag on the length, and the necessary correction found. The difference between the end of the tape and the cross on the picket-head was read off with the aid of finely-divided ivory scales. The results of the four measurements are given in the following table, after being corrected for the error of the tape, for temperature, and for tension :—

SEILA BASE.

Section.	1st measurement.	2nd measurement.	3rd measurement.	4th measurement.	Mean.
	m.	m.	m.	m.	m.
I.	700·6486	700·6356	700·6303	700·6390	700·6384
II.	700·6282	700·6302	700·6168	700·6268	700·6255
III.	700·4882	700·4926	700·4912	700·4901	700·4905
IV.	800·6794	800·6924	800·6795	800·6782	800·6824
Sum ...	2,902·4444	2,902·4508	2,902·4178	2,902·4341	2,902·4368

Subtracting a correction of 0·0089 metre for the difference of level, and 0·0105 metre for the reduction to sea-level, we obtain for the length of the Seila base: 2,902·4174 metres ± 0·0043 metre. It will be observed that the third and fourth measurements, made at an average tension of about 15 kilogrammes, gave a smaller value for the length of the base than the two first, which were made at an average tension of 12 kilogrammes. The difference is due, in all probability, to the selection of erroneous values for the coefficient of elasticity of the tape. As this coefficient, and also that of thermal expansion, have been assumed, the above probable error is only relative. An error of 5 per cent in the temperature coefficient would make a difference in the final result of 0·00174 metre per degree centigrade of difference between the mean temperature at which the base-line was measured and that at which the tape was standardized. As the two

did not differ by more than one degree Centigrade, it is hoped that the error introduced from this cause is small enough to have no significant effect on the final result.

It is otherwise, however, with the error arising from any assumption of inaccurate values for the coefficient of elasticity of the tape, and, owing to the difference between the circumstances in which the base-line measurements were made and the more artificial conditions of the standardization, it is difficult to form any estimate of the amount, if any, by which these constants are in error. However, the length of the base as determined by measurement differs so little (0·03 metre) from the length which was obtained by calculation of the triangulation from the Feshn base in Beni Suef, which was measured some years later with Jäderin wires, to that of Seila in the Fayum, that it may be taken as being amply accurate enough for its purpose in the circumstances of the case.

Moqattam Base.

The next base was measured near Abbassia to the north of Gebel Moqattam as a part of the triangulation of Qaliubia and Daqahlia provinces.

The base is situated about one hundred metres to the north of the old Suez road; the eastern terminal is on the hillock near the first tower and a few metres to the west of the tower, and the western terminal is on rising ground close to the first bend on the Suez road.* The terminals consisted of gas-pipe cemented into concrete blocks, the tops of which were flush with the ground. In the top of each pipe was screwed a brass plug on which a finely engraved cross marked the actual end of the base-line; for protection a screw-cap was fitted outside the top of the pipe.

For the purposes of measurement, the base was divided into four sections, the various points being named A, B, C, D, E, from east to west. A, the east end of the base, was the point D of the triangulation network.

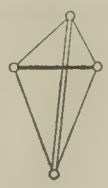

Fig. 3.
Moqattam base extension.
Scale 1 : 300,000.

* The eastern terminal has since been removed. The tower, though the first one met with after leaving Abbassia, is known as Second Tower, the first having been in Abbassia.

The intermediate points were marked by stout wooden pickets flush with the ground; on the top of each of these pickets a zinc plate carrying a fine transverse line was fixed.

The measurements were made with the 50-metre Jäderin wires which had recently been acquired by the Department. In actual measurement the wires were attached to light cords which passed over pulleys supported on movable brackets which were carried on wooden trestles, while the free end of the cord bore an attachment on which leaden weights of different sizes could be hung in order to produce the desired tension in the wires. Four trestles were used so that while one 50-metre length was being measured the next two could be prepared and placed in line. Between the wire and the cord, at each end, a spring balance was introduced ; at one end this simply served to show when the tension was approximately correct and to lessen possible shocks to the wire. At the other end the balance was of a finer description and could be read by estimation to tensions of 0·05 of a kilogramme. The combination of the steel and brass wires gave a means of finding the working temperature. The wires had been standardized in Sweden at a tension of 10 kilogrammes weight, but, on account of difficulties with the spring-balances, tensions of 7 kilogrammes were used; the finer spring-balance was read simultaneously with the scales on the wires and the necessary corrections were made in computation.

After the three intermediate marks had been placed they were found to be respectively 10, 10 and 1 centimetres out of the direct line, all in the same direction, but the corrections in length due to inaccuracy of alignment were negligible. Operations began on June 2nd and lasted till June 8th.

The procedure adopted was to align the tripods which marked the ends of the wires by means of a theodolite placed 20 metres behind one sectional mark and collimated on it and the next.* The tripods were first set up at approximate distances of 50 metres, but with the tripod-heads well out of line ; then, commencing with the farthest, the heads were brought into line and clamped ; finally the tripod over the sectional mark was placed in position. Similarly the second half of the section was aligned by

* Extra tripods up to a total of eleven were employed on this base to expedite the work.

placing a tripod over the penultimate tripod of the first half and proceeding as before. In this way the danger of moving the last tripod was minimized.

At the beginning and end of each section, the horizontal distance, in the direction of the base, between the needle in the tripod head and each terminal mark of the sections was found by setting up a theodolite on a perpendicular off-set from the mark, and measuring on an ivory scale the distance when it was small, and on a 20-metre steel tape when it was more than 30 centimetres.

Preliminaries having been settled, two trestles were placed in position to support the wire, and the movable brackets adjusted until the wire hung just clear of the needles. All being ready one of the observers signalled with a whistle and simultaneously each reader noted the scale divisions opposite his needle-point and the tension was recorded. The wire was then shifted slightly and a second, and then two more observations made. This completed a set with one wire, which was then unslung and exchanged for the other, when the complementary set was made. The wires when not in use were supported by men, so that their temperature would be that of the air, and that there would be no chance of undue heating from contact with the soil.

As soon as one 50-metre length was completed, the trestle at the beginning was carried forward to the next vacant tripod, while the fifth observer commenced finding the difference in altitude between the tripod heads. While the readings were in progress, one of the observers took the air temperature with a sling thermometer, but no ultimate use was made of this in computation.

The scale readers occasionally changed ends, to eliminate as far as possible any tendency to personal equation in reading or estimating scale divisions.

Work proceeded without noteworthy check except on two occasions, on one of which it was necessary to increase the tension to 11 kilogrammes in order to clear a bank. The other difficulty occurred at the west end of the base where the point E is situated on the top of the small but steep hillock, so that the last tripod, which overshot the terminal point by 10 metres, was not visible from the penultimate one. To get over the difficulty the 25-metre wires were brought into use and the last 14·5 metres measured from the last tripod to the terminal point with the tape swinging free. On the return measurement this difficulty was

avoided by starting from point E and finishing on level ground. The length was :—

Section.	Forward.	Back.	Mean.
	m.	m.	m.
1	1000·0164	·0031	·0098
2	1000·5592	·4424	·5008
3	1000·3908	·3691	·3800
4	389·4292	·4229	·4260
Sums ...	3390·3956	·2375	·3166

The probable error was ± 0·0420 metre, or one part in 80,000.

As the result of the operations, it was found that the heavy trestles were too cumbersome and delayed the work considerably, and in future work these were discarded in favour of ranging rods held in position by chain-men, until the new pattern apparatus designed by M. Guillaume was received in 1906.

Gebelein Base.

With the transfer of the second and third order triangulation to Upper Egypt, bases were first measured at Gebelein in the province of Qena and at Ambir in that of Girga.

The Gebelein base was measured on April 5–8, 1902. The site lay about four kilometres south-west of Gebelein, in the desert where the ground was level and favourable for the work. The base was divided into two sections each of which was about a kilometre long, and the terminals of the base and another point near the middle were marked by concrete blocks in which iron pipes were set each containing a brass plug; on the upper surface of this cross lines were engraved, and an iron screw-cap was fitted over it for protection. The methods of using the Jäderin wires were the same as at the Moqattam base, which has been described. The southern segment was first measured once in each direction, and then the

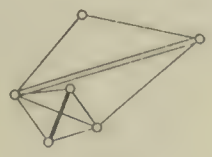

*Fig. 4.**

Gebelein base extension.

Scale 1 : 300,000.

* A diagonal has been omitted in the diagram.

northern segment was measured twice in the same manner. The results are given in the following table :—

Section.	1st measurement.	2nd measurement.	Mean.
	m.	m.	m.
North	1252·8085	·7813	1252·7949
South	1051·8899	·8915	1051·8907
Total	2304·6984	·6728	2304·6856

Probable error 1 in 250,000.

Ambir Base :

The next base measured was that at Ambir at the south end of Girga province on the east bank of the Nile. It was divided into two sections, each of which was measured twice with the 50-metre Jäderin wires. The finally corrected results were as follows :—

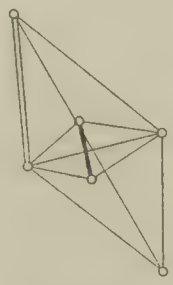

Fig. 5.
Ambir base extension.
Scale 1 : 300,000.

Direction of measurement.	North Section.	South Section.	Total.
	m.	m.	m.
N-S	1149·2323	1174·5103	2323·7426
S-N	1159·2442	1174·4677	2323·7119
Mean	1149·2382	1174·4890	2323·7272

Probable error, 1 in 180,000.

The length of this base was checked by calculating it through the triangulation from Gebelein base to the south, and the Tema base to the north.

Ambir base computed from Gebelein base = 2323·58 metres.
" " " " Tema " = 2323·29 "

Tema Base:

In May, 1903, near Tema, in Assiut province, the 100-metre steel tape was used to measure a base which was divided into 28 sections of about 100 metres each. The tape was supported on pickets which had been carefully aligned and levelled. Each section was measured four times: twice in each direction. The results were as follows:—

Fig. 6.
Tema base extension.
Scale 1 : 300,000.

Measurement.	Metres.
I	2800·2436
II	·2669
III	·3017
IV	·3019
Mean	2800.2793

Probable error, as deduced from a more detailed discussion (see Chapter XV), was 1 in 190,000.

Addendan Base.

This was the most southerly of the bases measured, and was situated about 800 metres from the Nile on the left bank of the river nearly opposite the village of Addendan. The spot is about 44 kilometres downstream from Wadi Halfa, and about five kilometres from the northern end of Faras village which is the boundary between Egypt and the Sudan.

The 100-metre steel tape was used in measuring this base, which was therefore divided into two sections of about 1,000 metres each, and twenty sub-sections each equal to the length of the tape. The terminal points alone were permanently marked, and for these, iron tubes set in cement-concrete were used, the exact point being defined by two fine engraved lines on a brass plug within the tube; the central point and those marking the tape lengths were only used during the measurement and were not permanently marked. The base was aligned with a theodolite and

Fig. 7.
Addendan base extension.
Scale 1 : 300,000.

wooden pickets were placed at intervals of 20 metres so that their heads were on grade; the level of each was determined. These pickets supported rollers on which the tape lay while in use.

The measurement was carried out on the 3rd and 4th of October, 1903, times being selected when the wind was very slight and there was no sun; the very early hours of the morning and the evening about sunset were therefore utilized.

Observations for azimuth were made with an 8-inch micrometer-theodolite reading to 1″ on the horizontal circle; the vertical arc was furnished with verniers only, and angles could be read to 10″.

The star Polaris was observed at its eastern elongation on two nights, ten sets of observations being taken in all, which gave an azimuth of 54° 6′ 49″ of E. for the line of the base with a probable error of ± 0″·7.

The results were as follows:—

Section.	1st measurement.	2nd measurement.	3rd measurement.	4th measurement.	Mean.
	m.	m.	m.	m.	m.
I ...	1,000·5540	·5884	·5475	·5947	1,000·5712
II ...	1,000·6294	·6520	·6412	·6629	1,000·6464
	2,001·1834	·2404	·1887	·2576	2,001·2176

Probable error, 1 in 200,000.

DAKKA BASE:

In order to compute the chain of small triangles which spanned the Nile Valley between Wadi Halfa and Aswan, another base was measured at Dakka on the left bank of the river, besides that at Addendan which has been just described. The 100-metre steel tape was employed, and the work was carried out on December 21-23, 1903. The total length was 2,699 metres, which for the purpose of measurement was divided into three sections of approximately equal lengths. The procedure was the same as at Addendan. Each section was measured twice in opposite directions, the

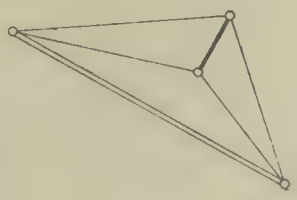

Fig. 8.

Dakka base extension.

Scale 1 : 300,000.

tension employed being 10 kilogrammes in one case and 15 in the other. The results obtained were as follows:—

Section.		1st measurement.	2nd measurement.	3rd measurement.	Mean.
		m.	m.	m.	m.
I.	N.	900·2099	·2281	·2374	·2251
	S.	·3566	·3474	·3522	·3521
II.	N.	900·4047	·4103	·4114	·4088
	S.	·4449	·4347	·4380	·4392
III.	N.	900·6429	·6631	·6611	·6557
	S.	·7394	·7208	·7329	·7310
IV.	N.	— 2·2862	— ·2858	— ·2859	— ·2860
	S.	— ·2856	— ·2857	— ·2857	— ·2857

Probable error, 1 in 125,000.

The mean length is given by deducting the length of Section IV from the sum of Sections I, II and III, and is equal to 2699·1203 metres.

Khattara Base

The base at Khattara on the left bank of the river a little to the north of Khattara railway station, and about 15 kilometres downstream of Aswan, was measured in February, 1904, and was 2,550 metres in length. The 100-metre steel tape was employed, as at Dakka and Addendan, for these three bases were used to compute the triangulation which covered some 400 kilometres of the Nile Valley at a part where it was very narrow. The cultivation nowhere occupied more than a narrow belt of land a few hundred metres wide at most, and usually formed disconnected patches, between which the desert came down to the river edge. The whole distance was marked out into twenty-five sections of approximately 100 metres each, corresponding to one tape length. The terminal points were marked in the usual way by brass bolts set in iron tubes, which were in turn set in blocks of concrete. The method of procedure was

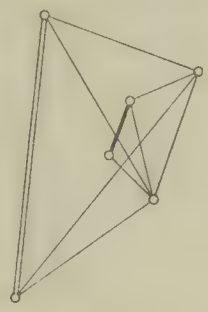

*Fig. 9.**

Khattara base extension.

Scale 1 : 300,000.

* A diagonal is omitted in the figure.

the same as that employed at Addendan and Dakka, except that the tape was strained by means of a weight running over a pulley, instead of a spring balance. Each section was measured four times, in each direction, both in the morning and in the evening.

The results obtained were as follows :—

Section and Direction.		1st measurement.	2nd measurement.	3rd measurement.	4th measurement.	Mean.
		m.	m.	m.	m.	m.
I.	N-S	699·8822	·8978	·9493	·9502	·9130
	S-N	·8519	·8627	·9378	·9721	
II.	N-S	700·4974	·5374	·5254	·5274	·5292
	S-N	·5310	·5460	·3263	·5426	
III.	N-S	700·3364	·3704	·4142	·3982	·3850
	S-N	·3601	·3854	·4105	·4046	
IV.	N-S	400·1073	·1058	·1102	·1213	·1110
	S-N	·0966	·0934	·1391	·1142	
V.	N-S	48·9506	·9496	·9509	·9514	·9506
	S-N	·9510	·9500	·9506	·9506	
Totals... ...		2,549·7822	·8492	·9572	·9663	·8888

Probable error, 1 in 200,000.

Roda Base:

In April, 1904, a base was measured near Roda, in Minia province, between triangulation points numbers 64 and 66 of the second-order triangulation. The base was 2,741 metres long, and was divided into ten short sections, of which the lengths are given in the table below.

The first section was longer than the others since it was measured at first with the 50-metre wires, one of which, however, broke after the first measurement. The other sections, with the exception of the ninth and tenth, are 11 lengths of the 25-metre wires. The measurement was carried out with the 25-metre Jäderin wires and the wires were strained by means of weights carried by wires running over small wheels mounted on ball bearings. The wheels were carried on stout rods which were steadied by hand, as these had been found to give more accurate results than the trestles used previously.

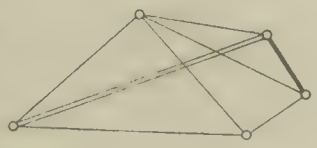

Fig. 10.

Roda base extension.

Scale 1 : 30,000

The site was on a newly-made level canal bank, and was connected to the second order triangulation by the base extension network shown in fig. 10.

The sections of the base were each measured twice in opposite directions. The results are given in the following table :—

Section.	1st measurement.	2nd measurement.	Mean.
	m.	m	m.
I.	550·1283	·1276	550·1279
II.	275·0794	·0790	275·0792
III.	275·1099	·1085	275·1092
IV.	275·0744	·0750	275·0747
V.	275·0686	·0676	275·0681
VI.	275·1436	·1446	275·1441
VII.	275·0817	·0786	275·0802
VIII.	275·0324	·0355	275·0339
IX.	250·1561	·1549	250·1555
X.	14·9834	·9834	14·9834
Total...	2740·8578	·8547	2740·8562

Probable error, 1 in 1,600,000.

FESHN BASE :

A base was measured at Feshn in Beni Suef province, November 10-16, 1904, with the 25-metre Jäderin wires in order to complete the triangulation of that province. The wires were strained in the same way as at the Roda base above described. The network of the base extension is shown in fig. 11.

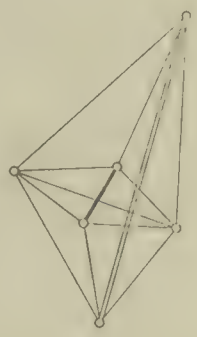

Fig. 11.

Feshn base extension.

Scale : 1 : 300,000.

The total length of 2,705 metres was divided into four sections, and each section was measured twice in opposite directions. The results were as follows :—

Section.	1st measurement.	2nd measurement.	Mean.
	m.	m.	m.
I...	575·1944	·2172	·2058
II...	800·0381	·0156	·0268
III...	824·9009	·8759	·8884
IV...	504·7918	·7782	·7850
Total...	2704·9252	·8869	2704·9060

Probable error, 1 in 190,000.

Tel-el-Kebir Base:

This base was measured on December 22-24, 1905, for use in computing the second order triangulation of Sharqia province. It was situated near Tel-el-Kebir in the Wadi Tumilat on the edge of the desert. The terminal points were marked as usual by brass plugs on each of which was engraved a cross; the plugs were screwed into iron tubes, which were set in blocks of concrete. The base was measured with 25-metre Jäderin wires, and Guillaume's apparatus for using them. It was measured in one section which was worked twice in different directions. The results were as follows:

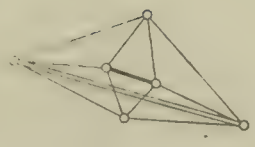

Fig. 12.
Tel-el-Kebir base extension.
Scale 1 : 300,000.

First measurement	2,105·2580	metres
Second measurement...	2,105·2215	„
Mean	2,105·2398	„

Probable error, 1 in 180,000.

Waqed Base:

A base 3,528 metres long was measured at Waqed at the southern end of Beheira province, on December 10, 1906. Jäderin's 25-metre wires were used with Guillaume's apparatus. The base was measured twice in one section, the direction of measurement being different in each case. The terminals were marked by iron tubes set in concrete, the exact point being a cross engraved on a brass bolt which was screwed into each tube. The results are as follows:

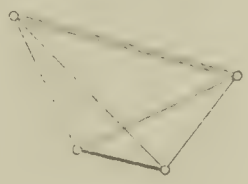

Fig. 13.
Waqed base extension.
Scale 1 : 300,000.

First measurement	3,528·2454	metres
Second measurement...	3,528·2421	„
Mean	3,528·2438	„

Probable error, 1 in 3,000,000.

RAS EL KHALIG BASE:

A base was measured at Ras el Khalig in in north-eastern Gharbia on February 25-28, 1907. The 25-metre Jäderin wires were used with the Guillaume apparatus. Like the Waqed base it was measured in one section and the measurement was repeated, being made in two different directions.

The results were:—

First measurement ...	3,897·0116	metres.
Second measurement ...	3,897·0230	„
Mean...	3,897·0173	„

Probable error, 1 in 1,000,000.

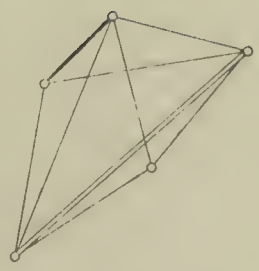

Fig. 14.

Ras el Khalig base extension.

Scale 1 : 300,000.

HALQ-EL-GAMAL BASE.

A base was measured in the north-eastern portion of Beheira in connection with the second order triangulation with the 25-metre Jäderin wires on August 11–12, 1907.

The base was divided into two portions, each of which was measured twice, the two measurements being made in opposite directions. Guillaume's apparatus for straining the wires, for marking the end of each wire length, and for levelling was used. The results were as follows:—

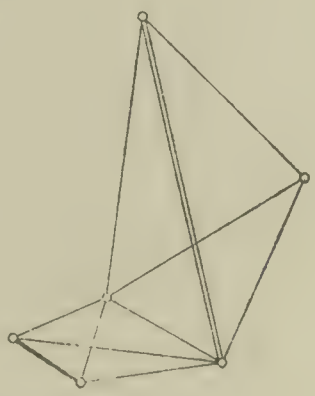

Fig. 15.

Halq-el-Gamal base extension.

Scale 1 : 300,000.

Section.	1st measurement.	2nd measurement.	Mean.
	m.	m.	m.
I.	1,553·6592	·6729	1,553·6660
II.	1,714·8172	·8137	1,714·8155
Sum...	3,268·4764	·4866	3,268·4815

Probable error 1 in 700,000.

CHAPTER XIII.

Triangulation.

When the Survey Department was formed in July, 1898, the most urgent need was a reliable triangulation which should ensure the positions of a series of points being accurately known in order that the land-measurements might be controlled thereby and that the small errors of measurement which inevitably occur might be prevented from accumulating to an amount which would injuriously affect the practical accuracy of the work. As the yearly out-turn of work was on no account to be delayed, it was very difficult, as has been explained in the foregoing pages, to provide a satisfactory triangulation at once. The standards of length and the measurement of the bases had to be improved as time went on and as opportunity offered; and a similar procedure was followed in the case of triangulation, but as an essential preliminary the computation of the observations was at once taken out of the hands of the observers and entrusted to an independent computing staff under the direction of an experienced mathematician, who describes in Chapter XV the methods which were gradually developed under his direction.

Although theodolite traverses were adopted in 1895 in order to control the chain survey, no systematic triangulation then existed. That which had been executed by the cadastral survey of 1878–1888 had only been carried out in the Fayum, Qaliubia, Gharbia and Menufia provinces; in none of these was it complete nor were the different networks joined together; it was of inferior accuracy and the majority of the marks had been lost.

In Sharqia province some of the points of an elementary type of triangulation carried out under the Ministry of Public Works for topographical purposes * had been utilized and Mr. Fuller, in 1895, recommended the extension of this triangulation to the Fayum and Giza provinces in order to prepare a basis for the more complete survey which the re-assessment of tax demanded. This triangulation had

* See p. 105.

grown out of the older cadastral survey of 1888, as already explained, and had adopted its methods to a large extent. Sufficiently accurate to furnish a basis for a plane-table survey which was carried out by graphical methods, and of which the detail, though plotted to a scale of 1 : 10,000, was only published on the scale of 1 : 100,000, it was incapable of controlling measurements made for a survey of landed property on the scale of 1 : 4,000. The methods of observation and computation which were employed have already been described, and, though the marking of points had latterly been effected by means of lengths of rail or angle-iron sunk vertically in the ground, they were neither sufficiently stable nor inconspicuous enough to furnish any guarantee of permanence. Still, the reassessment of the land-tax had to be carried on at a rapid rate in order that it might be completed within the period of ten years which had been decided upon, and any means of controlling the theodolite traverse by an independent class of work was valuable ; nevertheless, when discrepancies arose it was at times difficult to determine whether the fault lay with the triangulation or the theodolite traverse.* These two operations were at first carried out by separate departments, which led to their being less adapted to the end in view than if they had been carried out in close agreement ; but the formation of the Survey Department in July, 1898, rendered it possible to remove this difficulty, though, by this time, the triangulation had been finished in the province of Giza, much of the traverse work there was done, and a few villages were already being surveyed in detail. The triangulation was already being used as a control for the traverse but there were two sources of error which had been imperfectly removed ; namely, the error due to the base having been measured with a steel band without any correction being applied, and that due to the azimuths employed being magnetic ; the latter had to some extent been compensated for by correcting here and there the azimuth of a side of the theodolite traverse by an observation on the sun, but this amounted to controlling the triangulation to some extent by the traverse. In July, 1898, there still remained five months in which something might be done, since the basin lands of Giza province would be flooded in September and would not be dry enough to work on until the end of November at

* Cf. p. 126.

the earliest. A base at Badreshein and another at Matania in the El Ayat district of Giza province were re-measured * and the azimuth of a side of the triangulation (points Nos. 159-158) was determined astronomically by observation of Polaris at elongation; the results thus obtained were utilized to correct the triangulation so as to afford a control upon the lines which were traversed on the village lands.

The inherent defects of a system which permitted, or at least did not prevent, the measurement of two angles only and the determination of the third by subtracting the sum of the other two from 180°, and which allowed all the computation to be done by the observer, were soon apparent. A case occurred where one factory chimney had been mistaken for another when observing from the second station, but neither the angle book nor the computations showed this and it was only detected by a point being found to be some 200 metres out of its computed position.

A reliable control of the theodolite traverse was, therefore, an absolute necessity, but this had to be obtained without delaying the cadastral survey, which limitation rendered it impossible to introduce a high-grade system of base-measurement, computation, and triangulation, at once. To do so would have necessitated a period of transition during which a staff would have been trained, instruments procured, and a thoroughly efficient system of second order (or perhaps even first order) triangulation observed. But the interval of ten years which had been laid down as the period within which the cadastral survey had to be completed, imposed onerous conditions which would admit of no such delay, so that the best that could be done was to start at once with improved methods of base-measurement, observation, and computation in the next province, and energetically push on preparationsf or triangulating subsequent provinces in a more adequate manner. The Fayum province was taken up after that of Giza, since its isolated position to the west of the Nile Valley rendered it more suitable for surveying under a system which inevitably would not be up to the standard of later work. In this way the chain of triangulation up the Nile Valley would be of a satisfactory quality and whenever the Fayum was re-surveyed its triangulation could be controlled by the first order chain of triangulation in the valley which would then probably be complete.

* See Chapter XII, pp. 175-179.

Just as for the base-measurements where five-metre fir rods were first used, then a 100-metre steel tape, then Jäderin wires of steel and brass, and finally 24-metre Jäderin wires of invar standardized with the aid of the Brünner-Ibañez four-metre standard platinum bar; so the triangulation of the hydrographic survey was first replaced by a major and a minor series of triangles, which were soon improved to the standard of normal second order, third order, and fourth order triangulations, the higher grade in each case controlling the lower, and finally a chain of first order (geodetic) work was undertaken. Also the instruments in use developed from being 6-inch vernier theodolites to those of a better and more accurate type, being replaced by 8-inch and 6-inch micrometer theodolites, and finally a 10-inch micrometer theodolite of the highest quality by Repsold is being employed for the first order work. In this way, it was possible to pass from a triangulation of very approximate accuracy in eighteen months to one of satisfactory second order type of which the accuracy was not inferior to the standard which is usually attained in Europe in work of this grade,* and this without delaying the out-turn of the cadastral survey.

Second Order Triangulation.

The triangulation of the Fayum province being transitional in character differed somewhat from the normal second order work, but the rules laid down for the latter were followed from 1899 until the present time; a few improvements and modifications were introduced as experience was gained and the accuracy improved, but the work was essentially of the same character throughout.

The limit of permissible errors which were admitted in the closure of a triangle of the second order triangulation was fixed at 5″.

The following instructions were issued to all observers employed on the second order triangulation in the Nile Valley in order to guard against variations of procedure in observing the angles and in marking the points:—

"The general form of the triangulation should be a line of quadrilateral figures having their angles situated on convenient heights on each side of the Nile Valley to the south of Cairo. The most advan-

* See p. 207.

tageous shape is the square and no angle should exceed 120° nor be less than 30°. At each station only the three sides and the two diagonals passing through it should be observed even though other principal stations may be visible, but this does not prevent the inclusion of secondary points which may be intersected from three or more principal points, although they are not themselves occupied. It will be found that sides of more than 25 kilometres lead to delay on account of bad visibility of the marks and inaccuracy from varying refraction. The best hours for observations are the two immediately after sunrise, and one in the afternoon shortly before sunset, and to utilize these hours it will generally be necessary to pitch the camp within easy distance of the point so that this can be reached about sunrise. Every principal station must be occupied.

"As soon as a station has been definitely fixed and the mark laid down, a sketch must be made giving sufficient detail to enable the point to be found by a stranger to the locality; check marks will also be placed in order to recover the exact original position of the mark should it be removed.

"Great care must be taken that the flagstaffs are placed vertically over the mark and are sufficiently stayed to resist the pressure of the wind.

"Angles will be read continuously round the horizon alternately clockwise and counter-clockwise and will close on the first or reference point; they will be read in all twelve times, viz., face-right and face-left on six zeros, a shift of 30° being made for each complete set. In no case should the closing error of a triangle exceed 5″.

"When the observations at a point have been completed they should be copied on to angle-sheets (Survey form No. 29), which will then be sent to the Central Office where the calculations will be made; angle-books in which the observations are booked in the field will also be sent to the Central Office as soon as filled up, and all documents relative to the triangulation will be handed over to the Director-General at the end of the season, or as soon as they can be dispensed with, in order that they may be filed for future reference in the Map Store.

"Fortnightly reports will be furnished by the observer on Survey form No. 18, together with a tracing of the triangles which have been reconnoitred or observed and the descriptions of the points."

A full discussion of the methods used for reducing the observations is given in Chapter XV.

Third and Fourth Order Triangulation.

The next steps in the chain of control after the second order triangulation are now the third and fourth order systems, the latter having been introduced in 1906.

The third order system in general consists of triangles whose sides now average about three and a half kilometres in length, the positions of the points being marked by angle irons let into the ground. Observations are taken with a 6″ micrometer theodolite, and consist of four independent sets of readings off four different zero settings. The maximum error of closure permitted in a triangle except under very special circumstances is eight seconds.

With the re-survey of the province of Sharqia the primary importance of speed diminished and among other improvements it was found possible gradually to train more triangulators and to add a fourth system of triangulation. This had long been desired as affording an additional control to the traverse work and greater facility in locating and correcting errors. In this province a fourth order point was placed approximately in the centre of each third order triangle and its position determined by resection, that is by observing from it on to four surrounding points whose positions had been already fixed. Resection on to three points if the relative positions are well conditioned is sufficient to determine a fourth order point, but as a precaution a fourth point was always included. Three of these points were invariably of a higher order than fourth. Observations were taken with a five-inch vernier theodolite, one complete round of observations being made. The maximum permissible angular error admitted in this work is thirty seconds.

Several modifications have been gradually introduced into the general procedure of these two systems of triangulation in the provinces of Beheira and Gharbia. The size of the third order triangle, when circumstances permit, is increased so as to allow of the inclusion of three fourth order points within each third order triangle without appreciably increasing the total number of points placed per unit area. By this means it is hoped that while the control is not weakened the cost of the work will be lessened. On the other hand cast iron tubes set in concrete or masonry and placed below the level of the ground have been substituted for the pieces of angle-iron hitherto employed

as marks. These were not only intrinsically more expensive but the cost of transport of materials to the site and the additional supervision and labour entailed added to the cost. It is hoped, however, that these stations being of a more permanent and less obvious nature will not be so readily tampered with as those which were placed in other provinces and thus the waste of money involved by re-observation at a later date will be considerably reduced.

The table on page 209 gives data of the work in the various provinces but it must be remembered that these are not strictly comparable for not only was the work being gradually modified and improved but the class of the personnel itself was altering as the result of training and experience.

In several estimates which were made from time to time * for a triangulation in Egypt it was always anticipated that the level character of the Delta would necessitate the employment of a large number of towers or scaffolds from which the lines of sight would pass over the trees and palm-groves; but in practice it was found possible to avoid the employment of these altogether and only in fifty-one cases (twenty per cent.) were buildings utilized. It was usually possible to find positions on canal banks, knolls, sand-hills, etc., from which the necessary lines could be seen if a small amount of clearing was done.

Nevertheless, the level nature of the country in the Delta was always inconvenient, for the only natural elevations were the canal banks which were rarely as much as six metres high, mounds on the sites of ancient villages which might be ten or twelve metres high, and the minaret balconies of mosques which were usually from seventeen to twenty metres above the ground. These had to be utilized if lines of greater length than usual were to be obtained, since the trees of the country interfered with the line of sight and any considerable amount of clearing was usually objected to by the owners. The marks on banks, mounds, and the ground in general, which were at first pieces of **T** or **L** iron about 1·0 or 1·2 metres long sunk in the ground, were furnished with a foot-plate to prevent their being removed. These were employed in the provinces of Daqahlia, Qaliubia, Giza, Beni Suef, Fayum, Minia, Assiut, Girga and Qena, but afterwards a tubular form of mark was adopted which was set in masonry and sunk out of sight below the

* Previously to 1898.

surface of the ground. The removal of triangulation marks by the inhabitants has throughout the work caused great delay, and often much additional expense. In Aswan province bolts were used, since the valley was so narrow that all the points were placed on the sandstone rock of the desert. In the other provinces of Upper Egypt also, a certain number of the points were placed on the limestone desert plateau and here, too, bolts were used ; they were of brass and were fixed in cement. Houses were not used if they could be avoided, because they were seldom stable enough to bear the theodolite and the observer without vibration, and since the flat roof is often used by the family, the signals were liable to be interfered with. Minarets had from time to time to be utilized in Lower Egypt, although they were not altogether free from objection. Some were not well constructed and were liable to move in windy weather ; the observations had to be made from the balcony and referred to the vane of the minaret which formed the point; and the balcony was often so narrow that the observer had to pass round the minaret in order to read the second microscope, all of which causes might affect the observations prejudicially.

The signals at first used were long poles with flags attached to them ; these were firmly stayed with wire to keep them in a vertical position. Soon, however, it was found more convenient and more economical to fix a signal made of a black and a white target set at right angles to each other on a pole over the mark and leave it so long as work was in progress in the district.

Much trouble was caused by refraction, and it often happened that signals which were clearly visible when placed by the reconnoitring party in the winter months were invisible from the neighbouring points when observations had to be made in the following summer. Again, the high masts and sails of boats passing along the canals, or the heated air from a moveable pumping-engine or from a burning brick-stack sometimes interfered considerably with seeing. Day observations were used throughout the second order triangulation and visual signals rather than heliographs were employed, since these gave results more quickly without falling below the standard of accuracy which had been laid down, but in Beheira and Sharqia provinces heliographic signals have been also used. Heliographers, however, were used for communicating between parties at a distance, and especially when working on opposite sides of the Nile Valley in Upper Egypt.

A general summary of the second order triangulation which has been executed exclusive of that which has been observed over the towns of Cairo and Alexandria, is given in the following table in order to show the character of the lines sighted.

STATISTICS CONCERNING SECOND ORDER TRIANGULATION OF EGYPT.

Province.	Total number of lines.	Total length of lines.	Mean of lines.	Number of lines from buildings. *	Length of lines from buildings. *	Mean of lines of buildings.*
		kilometres.			kilometres.	kilometres.
Aswan ...	93	1,446·5	15·5	—	—	—
Qena	88	1,208·1	13·7	5	63·3	12·7
Girga ...	55	787·9	14·4	5	77·6	15·5
Assiut ...	43	772·3	18·0	—	—	—
Minia ...	60	758·0	12·6	19	286·9	15·1
Beni Suef.	23	425·1	18·5	—	—	—
Fayum ...	116	917·8	7·9	—	—	—
Giza... ...	28	399·7	14·3	7	106·2	15·2
Qaliubia ...	35	337·3	9·6	34	372·4	11·0
Sharqia ...	78	1,036·1	13·3	28	393·9	14·1
Daqahlia ...	68	933·3	13·7	94	1,359·8	14·5
Menufia ...	27	399·3	14·8	34	509·6	15·0
Beheira ...	61	997·2	16·3	70	1,201·9	17·2
Gharbia...	92	1,584·7	17·2	118	2,006·4	17·0
Total ...	867	12,003·3	13·8	414	6,378·0	15·4

This network covers an area of 35,380 square kilometres and contains 356 points.

But in 1904 there still remained a large portion of the Delta which had never been triangulated since the detail survey of the provinces of Beheira and Sharqia had been carried out in 1892–1897 before the Survey Department was formed, and when the work was of a more elementary character.† Moreover, the work in Sharqia was mostly thirteen years old, so that by this time many changes had taken place and the landowners and the General Assembly applied to the Government that a re-survey might be made. Triangulation was therefore begun in 1905 and the province was finished in 1907

* A line with both ends on buildings is counted twice.

† See Chapter IX.

Twenty-nine points were occupied, and 78 sides were observed which formed 57 triangles; the average error of closure of a triangle was 2″·5 and the probable error of an angle was 1″·2. Beheira province was also taken up in 1907 and was finished in 1908.

In the Fayum province which was first taken up, the object was to prepare in the shortest possible time, a triangulation sufficiently accurate to control the traverse work and the detail survey which was to be plotted to the scale of 1 : 2,500. The two triangulators of the hydrographic survey were therefore moved into the Fayum at the end of 1898 where a major and minor network of triangles was reconnoitred and the angles were afterwards observed.

The major triangulation consisted of triangles having sides from eight to ten kilometres long; fifty-seven stations were occupied and a hundred and sixteen lines were observed, of which the average length was 8·7 kilometres. There were eighty-one triangles and the average error of closure of a triangle was 3″·8 while the probable error of an angle was ± 1″·5. The observations were made with a 25-centimetre micrometer theodolite by Stärke and Kammerer, of Vienna. A systematic method of observation was now introduced; observations were taken on six arcs, the instrument being set 30° further on the horizontal circle at the commencement of each arc; a complete observation consisted of a set of readings with both micrometers taken with the vertical circle both face-right and face-left.

After the Fayum province, those of Daqahlia and Qaliubia in the eastern part of the Delta had to be triangulated, being the only ones in Lower Egypt which had not been yet surveyed. The southern two-thirds of the area was highly cultivated and in the neighbourhood of Maimun, halfway between Zagazig and the Nile, there were dense groves of palms. This made the work difficult, for the time available did not admit of building elaborate towers, so such balconies of minarets as were sufficiently well constructed had to be utilized; twenty-one points had therefore to be placed on buildings, a larger number than in any other province. The second order triangulation in this part consisted of polygons which were carried from Cairo, where a base was measured close to Abbassia, through Qaliubia and Daqahlia, passing round the mass of palm-groves near Maimun. This gap was filled in by the smaller triangles of the third order triangulation. The base extension near Abbassia included the point

on the Moqattam Hill occupied by the transit instrument of the British Transit of Venus Expedition of 1874.* This is the point of which the longitude 2 h. 5 m. 6 s. ·24 E. of Greenwich, as determined by the expedition of 1874, is still the fundamental longitude for Egypt, although it is practically certain that its value needs some slight correction as is shown in the discussion of the principal geographical positions in Egypt in Chapter XV. When the Fayum province was being triangulated no satisfactory connection with the Transit of Venus station of Moqattam Hill could be made, since the triangulation of Giza province was not accurate enough; a provisional longitude of a point at Medinet el Fayum was therefore obtained by exchanging chronometer signals between it and the Abbassia Observatory, while the latitude was obtained by astronomical observations of Polaris. When the final connection of the Fayum triangulation with the valley triangulation was made in 1906 the errors in latitude and longitude proved to be 3″·6 and 10″·2 respectively.

Taking the second order work in Qaliubia and Daqahlia provinces together, forty-five stations were occupied and one hundred and three lines were observed, of which the mean length was fifteen kilometres; sixty-four triangles were laid out, of which the average error of closure was 2″·4 while the probable error of an angle was ± 0″·91.

It had been intended, after completing the second order triangulation of these two provinces, to extend it southwards as a chain of quadrilaterals up the Nile Valley, and to connect these with the Fayum triangulation in passing, but circumstances prevented this scheme from being carried out and necessitated the adoption of a much more inconvenient one. The recent low floods had enabled work on the Aswan Dam and the Assiut Barrage to be pushed on more rapidly than had been originally estimated, so that the reservoir was first filled in the beginning of 1903. This enabled a large area of land in the provinces of Assiut, Minia and Beni Suef to be converted from basin to perennial irrigation, thereby greatly increasing its value. It became necessary, therefore, to leave these lands as long as possible in order that the new canals and drains should be made and that the changing value of the land should have time to take its new value before re-assessment

* Cf. "Observations of the Transit of Venus, December 8, 1874," edited by Sir George Airy, K.C.B., F.R.S., Astronomer-Royal.

of the tax was undertaken. Instead, therefore, of continuing a chain of triangulation up the valley, it was necessary to break off and make a fresh start at a point 600 kilometres further up the river, and then work southwards to the Sudan frontier near Wadi Halfa before turning northwards and descending the valley to join the earlier work at Cairo. Nothing could have been more inconvenient for the triangulator and the computer, but there was no means of avoiding the interruption of the work, and there was no time to triangulate this length of valley before commencing the detail survey of the southern districts. The most suitable point at which to recommence was Luxor, where the latitude and longitude had been determined in 1874 by Professor Auwers, of Berlin, on the occasion of the Transit of Venus in that year,* at the same time that the position of a point on Moqattam Hill was being fixed by the British expedition. When, four years later the triangulation had been carried down the Nile to join that of Qaliubia and Daqahlia, the following errors of closure were found :—

Error of closure in latitude at the Venus station on Gebel Moqattam	+ 4″·12
Error of closure in longitude at the Venus station on Geel Moqattam	−11″·72
Error of closure in azimuth of Great Pyramid-Venus Station line	−28″·1

In 1902, triangulation of the second order was commenced in the provinces of Qena and Girga and the plan already mentioned of employing a chain of quadrilaterals along the Nile Valley was carried out. Base-lines were measured at intervals of about 150 kilometres, and at these astronomical observations for latitude and azimuth were made. The section of the chain between each pair of base-lines was computed as a whole to avoid the accumulation of errors, and to secure consistency.

The bases for the Qena-Girga section were at Khattara, near Aswan ; at Gebelein, in Luxor district ; at Ambir, in Nag Hamadi district and near Girga, in Tema district ; these have already been discussed in the preceding chapter.

In Qena province thirty-five stations were occupied and eighty-eight lines were observed, forming sixty-four triangles, of which the average error of closure was 2″·19 and the probable error of an angle was ± 0″·83.

* "Abhandlungen der königlichen Akademie der Wissenschaften." Berlin, 1877.

In Girga twenty-one stations were occupied and fifty-five lines were observed, forming forty-six triangles of which the average error of closure was 3″·04, and the probable error of an angle was ± 1″·16.

The triangulation of these two provinces and also of that of Aswan from Dakka to Esna was completed in 1903. The inundation of the cultivable lands from the middle of August till late in October reduced the time available for surveying in Upper Egypt, so that the staff of the detail survey had to be increased in order to keep up to the original programme. This involved an increased out-turn from the triangulators who were now working in a part of the country where much time was inevitably spent in crossing from one side of the Nile to the other. It became necessary, therefore, to stop the second order triangulation at Dakka (lat. 23° 10′ N.) and employ third order triangulation only between this point and Wadi Halfa. This did not introduce any appreciable error into the work for the valley in this part is very narrow and the amount of cultivable land is extremely small; it is rarely as much as two kilometres wide, and the cultivation consists of patches, each a few hundred metres long by two or three hundred wide. Beyond this, the desert commences. In the 250 kilometres of valley between Dakka and Faras, which is the point where the administrative boundary between Egypt and the Sudan crosses the Nile, there are only 23,000 feddans (about 10,000 hectares) of land of all kinds recorded in the land-registers. This length of valley was therefore covered by a chain of 173 triangles having an average length of side of 4,500 metres; the average error of closure of a triangle was 2″·4, the greatest being 7″·5; the probable error of an angle was ± 0″·9. The triangulation was extended to Wadi Halfa by an additional group of 39 triangles, of which the average error of closure was 2″·2. At Wadi Halfa one of the terminal points, No. 60, was the same as that whose longitude was determined by Colonel the Hon. M. G. Talbot, R.E., in 1893 and 1897. At this time there was still a gap in the chain of triangulation near Aswan, so that the positions of the points in Nubia were at first computed with reference to a provisional longitude of the south point of Addendan base in order that the traverse work might be computed, the field-sheets projected, and the traverse points plotted on them. Later, however, when the Nile Valley chain was complete, the co-ordinates of these points were brought into agreement with the rest of the system.

In 1904, besides completing work in Aswan, the second order triangulation was carried northwards from Girga province through those of Assiut, Minia and Beni Suef, where it was connected with that of the Fayum which had been done five years before. In these provinces of Assiut, Minia and Beni Suef, 17, 26, and 7 stations respectively, were occupied, and 43, 60, and 23 lines were observed ; the sides were rather longer than had usually been the case since the Nile valley attains its greatest breadth in this part ; in Assiut, the mean length of side was 22 kilometres and in Beni Suef it was 24, while in Minia it was 15 kilometres. Bases were measured at Roda, Tema, and Feshn as already described.

The number of triangles in these three provinces and the average error of closure of a triangle as well as the probable error of an angle is given in the following table :—

Province.	No. of triangles.	Average error of closure.	Probable error of an angle.
Assiut	35	2″·0	±0″·8
Minia	37	2 ·0	±0 ·8
Beni Suef	15	2 ·4	±0 ·9

In 1905 a few points in Minia which had not been observed during the previous year were completed and the chain of triangulation was carried over Giza province in order to connect the triangulation of Upper Egypt with the "Transit of Venus" station on Moqattam Hill, and with the triangulation of Qaliubia and Daqahlia provinces which had been observed in 1900 and 1901. This was done rapidly and for topographical purposes, so that it was not of quite the same order of accuracy as the triangulation of the rest of Upper Egypt. The resulting network has given a system of points amply adequate to the needs of the cadastral survey, though it can be improved by a general discussion of the results as soon as time for this is available. It was now possible for the first time to base a map of Egypt on a connected triangulation carried out from Damietta in the north to Wadi Halfa in the south, and extending over 9° 36′ of latitude or 1,050 kilometres measured along the meridian.

The triangulation had been commenced in 1899 in Fayum province and following this, in 1899 and 1900, the provinces of Daqahlia and Qaliubia were triangulated ; in these the central polygon was employed as in the general figure, and a chain of them extending from Damietta to Cairo was completed by June, 1901. In Upper Egypt the conditions were different, for the area to be surveyed lay in a valley flanked by steep cliffs ; the quadrilateral was, therefore, adopted as the principal figure of the triangulation, and, with the exception of some more complex figures in the extension of the various bases, was exclusively employed to the south of Cairo. The following table shows the date of commencement and conclusion in each province :—

Province.	Period of Operations.
Qena	January 1 to November 15, 1902.
Girga	November 20 to December 31, 1901, and February 1 to May 5, 1903.
Aswan	November 10, 1902, to February 1, 1903, and November 15, 1903, to March 1, 1904.
Assiut	May 6 to June 1, 1903, and December 25, 1903, to April 30, 1904.
Minia	March 1 to May 15, 1904, and October 10, 1904, to January 20, 1905.
Beni Suef	May 16 to June 15, 1905, and October 15 to December 31, 1904.
Giza	June 16 to July 20, 1904, and February 1 to April 1, 1905.
Sharqia	November 10, 1905, to June, 1906. August, 1906 to March, 1907.
Beheira	November 25, 1906, to October, 1907.
Gharbia	March, 1907, to December, 1908.
Daqahlia ... ... / Qaliubia ... ... \	December, 1900, to October, 1901.
Fayum	October, 1899, to June, 1900.

It should be stated that the closing errors of the triangles are the averages of the numerical values of the errors, and the probable errors of the angles have been derived from them by C. F. Peters' formula.

Statistical Data of Second Order Triangulation.

Provinces.	Extent in square kilometres.	Time taken in man-days.	Stations occupied.	Lines observed.	Triangles.	Average length of sides.	Cost.	Cost per square kilometre.	Cost per Station.	Average error of closure of triangles.
						kilometres.	L.E.	L.E.	L.E.	
Fayum	1,881	293	57	116	81	9	703	0·374	12·3	3″·80
Qaliubia ... } Daqahlia ... }	3,398	270	45	103	64	15	1,416	0·416	31·5	2″·40
Qena	2,544	153	35	88	64	15	599	0·235	17·1	2″·19
Girga	1,495	165	21	55	46	16	612	0·409	29·1	3″·04
Aswan	3,500	321	39	93	77	17	985	0·281	25·3	2″·48
Assiut	2,122	222	17	43	35	22	1,031	0·486	60·6	2″·04
Minia	2,006	168	26	60	37	15	962	0·480	37·0	2″·02
Beni Suef	1,170	92	7	23	15	24	256	0·219	36·6	2″·40
Giza	1,160	71	10	28	20	19	327	0·282	32·7	2″·34
Sharqia *	3,420	—	29	78	57	14	—	—	—	2″·50
Beheira	4,558	212	29	61	38	17	852	0·187	29·4	1″·80
Menufia	1,572	} 360	9	27	17	14	} 1,400	0·172	31·2	} 2″·30
Gharbia †	6,554		36	72 (approx.)	58 (approx.)	17 (approx.)				2″·47 incomplete.
Egypt	35,380	2,327	356	847	609	15·0	9,143	0·286	28·0	2″·55

* The triangulation of Sharqia province was done by various parties in the intervals from other work and it is not possible to estimate the cost.

† Gharbia is not yet completed.

Statistical Data of Third and some Fourth Order Triangulation up to December 1907.

Province.	Extent in square kilometres.	Time taken in man-days.	Stations occupied.	Lines observed.	Triangles.	Average area in square kilometres. (4)	Average length of sides in kilometres. (4)	Cost.	Cost per square kilometre.	Cost per station.	Average error of closure of triangles. (4)
								L. E.	L. E.	L. E.	
Fayum	2,100	467	239	654	330	6·4	4·5	848	0·402	3·55	6″·6
Qaliubia	930	443	222	537	357	2·6	2·8	562	0·604	2·53	3″·7
Daqahlia...	2,520	1,034	574	1,446	902	2·8	3·1	1,475	0·585	2·57	4″·5
Qena	1,447	543	306	696	467	3·2	3·2	885	0·599	2·89	3″·3
Aswan	2,867	517	340	875	338	7·5	5·2	861	0·301	2·54	2″·5
Girga	1,441	479	229	590	355	2·9	3·0	956	0·663	4·17	3″·2
Assiut	1,950	433	227	758	379	5·6	4·1	938	0·481	4·13	2″·6
Minia	1,830	455	223	630	356	5·2	3·2	950	0·519	4·26	3″·0
Beni Suef	1,000	205	170	400	259	4·5	4·0	379	0·379	2·23	3″·6
Menufia	300	498	61	230	120	2·5	2·7	388	1·273	6·36	4″·0
Sharqia	3,420	3,744	933	2,337	2,105	4·0	3·2	4,615	1·349	4·95	4″·3
Beheira	3,243	4,155 (1)	768	2,320	1,850	3·8	3·7	3,046	0·939	3·96	3″·5
Gharbia	130	293 (3)	39 (2)	67	33	4·5	3·5	450 (3)	3·462 (3)	11·54 (3)	3″·3
Total... ...	23,178	13,671	4,331	11,540	7,551	4·2	3·6	16,353	0·706	3·78	3″·8

(1) In Gharbia and Beheira provinces owing to the introduction of fourth order triangulation which was sometimes observed by them, the working-days of assistants was included which was not done previously.

(2) Fifty points have been observed but only 39 have been finally accepted.

(3) These figures are not representative owing to the work being only in its initial stage and to the reason given in (2).

(4) Calculated for third order points only.

CHAPTER XIV.

Theodolite Traverse.

While in some countries the area included within the sides of the smallest series of triangles is divided up by straight chain-lines measured in the first instance from one triangulation point to another, and then by numerous tie-lines and subordinate lines, in others traverse lines are surveyed with a theodolite and chain which follow the most convenient course and frequently change direction. In the first system, which the British Ordnance Survey has mainly employed, no angular measurements are made, but all is done by means of accurate chaining; in the second system, a course is taken more or less directly from one triangulation point to another, and consists of a series of straight lengths which usually differ from one another in direction. The straight portions are measured with a steel band or chain and the angles which they make with one another are measured with a theodolite.

There are advantages which may be claimed for both methods, and, in any particular case, local conditions must determine which should be employed.

In Egypt the decision was mainly based on the fact that the elementary method of survey with plane-table and chain, such as was employed from 1892 to 1895, might be greatly improved and very fairly controlled by closed traverses executed with a theodolite and a chain. By this means, a number of points could be located of which the algebraic sums of the errors in angular and linear measurement could be limited to a certain range dependent on the efficiency of the staff employed. These errors could be distributed among the angles and sides in the most favourable manner and thus a control was obtained for the chain survey which started from and closed on the points thus determined.

As has already been stated, Sir Bamfylde Fuller, who was in Egypt in the latter part of 1895 to report on agricultural methods and development, was asked to report upon the State Lands Survey also. His recommendations were made with a view to introduce a general

improvement of the methods used so as to obtain maps and land-registers analogous to those of the Revenue Survey of India.

Theodolite traverses were to be introduced to control the chain survey and he strongly urged the provision of triangulation to which the traverses might be connected and by which they could be controlled. When this new procedure was introduced, almost the whole of Sharqia province had already been surveyed with the plane-table, as well as about two-thirds of Beheira; but the remaining villages were traversed with the theodolite and the points so determined served as a control for the detailed survey in which every holding was to be shown. After these two provinces were completed, theodolite traverses were made use of in all the others, at first without, but after 1898, invariably with the further control of triangulation.

In 1896, nine engineers were employed on theodolite traverse work, and fifty villages were completed in the first five months of the year. As soon as the provinces of Beheira and Sharqia had been completed, work was undertaken in Gharbia and then in Giza, where the triangulation of the hydrographic survey which had been observed in 1897 was utilized as a control, and thus for the first time triangulation became the real basis of the work. It has been already stated that this triangulation was not of sufficient precision to control adequately a land survey on the scale of 1 : 4,000, and, at times, it was doubtful whether a discrepancy found to exist was necessarily due to inaccurate traversing, since the triangulation was at times not above suspicion. Still, it was of much assistance and checked such gross errors as the traversers might make.

The provinces of Gharbia and Menufia were, however, surveyed wholly by means of closed traverses which were used to control the chain survey and in them no triangulation existed, since the former was commenced in 1896, and the latter had to be commenced in 1898, when the triangulation staff was only sufficient to observe the angles of the network in the Fayum province.

The method of work for executing the theodolite traverses was at first as follows: The province under survey was divided up into sections of about 20,000 feddans (8.400 hectares) which approximated to districts, and these large blocks were traversed with care, the work being done by the more efficient of the staff, who also traversed the villages lying on the boundary; the less experienced staff was

distributed among the inner villages. The internal angles of each traverse-polygon were measured with a 5-inch theodolite reading to 30″; the telescope then being reversed, the observations were repeated, so that four vernier readings in all were obtained.

The azimuth of a side of the traverse was observed from time to time by measuring the altitude of the sun and simultaneously the bearing of the sun's centre, the time and the position of the place being approximately known.

The distances were chained twice, firstly with a chain measuring 5 qassabas in length, each qassaba (3·55 metres) being divided into twenty-four parts, and, secondly, with a special chain known as a "feddan" chain which was 20·409 metres in length. This latter chain was of such a length that the area of a square the side of which was one such chain was equal to 0·1 feddan. It was estimated that a traverser could complete an area of about 14,500 feddans (6,100 hectares) in a month of twenty-six days, and, allowing 10 % as needing correction, an effective monthly out-turn of about 13,000 feddans (5,500 hectares) was anticipated. The number of points which it was desirable to fix per unit of area was not laid down, but there were on the average four points in Sharqia and seven points in Beheira to each square kilometre; in Gharbia there were on the average five and a half points to a square kilometre; thus it will be seen that the number of points was very low for a country in which the land was so subdivided.

The statistical information which is now available, concerning the traverse work in the provinces of Sharqia, Beheira and Gharbia, is given in the following table.* Only part of Sharqia and Beheira provinces were traversed (see plan XX), but the whole of Gharbia was surveyed in this way; there was, however, no triangulation control.

* Communicated by Kamil Effendi Wali who was in charge of computation in 1898.

Province.	District.	Area * in feddans.	Traversed. from	Traversed. to	Number of points.	Number of points per square kilometre.
Sharqia	Zagazig	35,084	I 1896	V 1896	527	3·57
	Belbeis...	38,883	V 1896	VI 1896	625	3·82
	Miniet el Qamh...	45,654	V 1896	VI 1896	1,122	5·34
	Hehia...	14,939	IV 1896	V 1896	289	4·60
Beheira	Damanhur	46,075	VI 1896	VIII 1896	1,243	6·42
	Delingat	56,663	VII 1896	VIII 1896	2,106	8·84
	Shubrakhit... ...	60,811	VII 1896	VIII 1896	1,485	5·81
	Negila...	64,157	VII 1896	IX 1896	1,756	6·51
	Alexandria... ...	11,662	VIII 1896	X 1896	339	6·91
Gharbia	Kafr el Zayat ...	67,822	XI 1896	XII 1896	2,418	8·48
	Tanta	108,467	XII 1896	I 1897	2,758	6·05
	Santa	58,059	I 1897	II 1897	1,826	7·48
	Zifta	55,404	I 1897	II 1897	1,716	7·37
	Mehallet Kubra...	108,157	II 1897	IV 1897	2,918	6·42
	Dessuq...	64,642	III 1897	VI 1897	1,403	5·17
	Kafr el Sheikh ...	349,608	V 1897	II 1898	3,530	2·40
	Fua	83,876	VIII 1897	VI 1898	1,756	4·98
	Talkha...	111,439	XII 1897	III 1898	1,783	3·80
	Sherbin	409,826	III 1898	VI 1899	6,843	3·91
					Mean	6·24

The traverses of Giza and Menufia provinces were executed just before and after the formation of the Survey Department; in Giza the triangulation of the hydrographical survey was utilized as a control, but in Menufia none was available as already explained.

* These areas are only approximately correct.

The statistics for these two provinces are given here:—

Province.	District.	Area in feddans.	Traversed. from	Traversed. to	Number of points.	Number of points per square kilometre.
Giza...	Giza	49,919	III 1898	V 1898	1,363	6·49
	Embaba	92,059	XII 1897	III 1898	1,744	4·51
	Ayat	56,094	I 1898	VII 1898	1,210	5·13
	Saff	46,817	X 1898	V 1898	1,210	6·10
					Mean ...	5·56
Menufia	Tala	79,013	IV 1897	VIII 1897	1,610	4·80
	Ashmun	72,639	VIII 1897	VIII 1898	1,630	5·34
	Menuf	79,154	III 1899	X 1899	3,790	11·39
	Quesna	71,274	I 1900	VII 1900	2,935	9·96
	Shibin el Kom...	71,343	XII 1899	VII 1900	3,066	10·22

The records for Fayum are incomplete, but for the districts of Etsa, Fayum and Sennures 6,723, 3,911, and 4,251 marks respectively were placed, equivalent to 8·8, 10·7, and 7·0 per square kilometre, or 8·6 for the whole province.

The polygons were checked by adding up the internal angles and any error was divided among the angles.

At first wooden pickets were used to mark the points of the traverse, but these were soon lost or removed; then earthenware drain-pipes, 6 centimetres in diameter and about 30 to 35 centimetres long were tried, but these were too attractive to the "fellahin," who found them most useful in the irrigation of their fields, and the pipes were removed almost as fast as they were put down. Roughly dressed limestone blocks were next tried and proved fairly satisfactory; they were conspicuous, heavy to transport and did not indicate very precisely the point referred to, but the people were accustomed to the use of boundary-stones, and in some districts they were not removed to any very great extent; in others, however, more than half the points were taken away during the detail-survey. They were usually 20 centimetres by 20 centimetres in section and about 50 centimetres in length, but varied considerably. Since there is no stone in the Delta all these stone marks had to be quarried near Cairo and sent by rail to the station nearest to the village where work was being carried on. From this point the inhabitants of the village transported them to the village

and set them in the positions indicated by the surveyor. This was a small undertaking in the early stages of the work, when only three to four points per square kilometre were being placed, but later, in 1899, when six times the number were employed and the work was being pushed on more rapidly, the charge became burdensome and the cost of transport and placing was henceforth borne by the Government.

In 1898, when the Survey Department was formed and when the decision to commence the re-assessment of the land-tax forthwith had been arrived at, it was necessary to examine this branch of the work in order to see what improvement was possible in order to increase both the rapidity and the accuracy of the work. The experience of the past two years furnished the necessary information and several changes were at once made. Transit theodolites were substituted for those in use which had a central support or were of the Everest pattern in which reversing the telescope was, therefore, somewhat troublesome and was likely to be omitted. Steel chains were substituted for those of wrought-iron wire which had been hitherto in use and which had been found to alter considerably in length; the measurement with two chains seemed to give a control which was more apparent than real, and the two measurements in opposite directions with a 20-metre steel chain were adopted; the number of points per square kilometre was increased from 4-6 to about 15-18; computation by means of traverse tables and Fuller's slide-rule was given up, and the co-ordinates of the points were calculated by the aid of tables of natural sines and cosines, and computing machines; the plotting of the points in the field-sheets was also greatly expedited by using a co-ordinatograph by Coradi, of Zurich, instead of the ordinary plotting scale.*

But the most urgent and important modification was to control the traverse by a reliable triangulation and an attempt to do this had been made already by using the work of the hydrographical survey in Giza; triangulation in the Fayum was commenced, but a year at least would elapse before it could be observed and computed. In order that work of the detail-survey might not be delayed, the small province of Menufia was commenced and surveyed by a series of closed traverses without a controlling triangulation; it was the last province treated in this way.

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* See Computation, Chapter XV.

The procedure followed in fixing and locating traverse points which should control the work of the chain-survey consisted in:—

1) selecting the lines to be traversed;

2) measuring the lengths and angles;

3) recording the descriptions of the points and the observations made.

Notice was sent to the province or district office of the names of the villages which would be traversed during the next month, and the "omda" of each village was given a printed notice explaining the nature of the work, and requiring that he or his representative should point out the boundaries of his village and note the positions of the marks which were placed.

The traverser made a circuit of the village boundary with the "omdas" of the village and of those which adjoined it, in order to determine its position, and make a sketch of it; he also enquired whether any portions of the village lay detached in other villages, or whether land of other villages was included in this one. If the boundary was very complicated he reported the case to his inspector for consideration, together with any suggestions for modifying it.

Marks were first fixed along the boundary and then along canal banks, roads, and on other convenient lines so as to provide a well-distributed system of points. During this stage of the work one measurement of the length of the sides was made.

It was laid down that the density of points should be about sixteen per square kilometre, and the maximum and minimum length of sides were fixed at 500 and 50 metres respectively. A descriptive list of all the points was made at this time, in which the position of the point was defined, and the name of the owner of the nearest plot was recorded as a guide to its recovery. When the marks had been placed and their positions registered, the angles were measured and the second measurement of the length of the sides was made. The angles were observed with 5-inch transit theodolites without vertical circles, the horizontal circles being read with verniers to 30″; readings were taken both with the telescope direct, and after it had been reversed in its trunnions. The expedient of measuring the length of the sides on two separate occasions instead of twice when the angles were being observed was only employed so long as it was difficult to keep both triangulation and traverse

sufficiently ahead of the chain-survey, as it enabled a small economy of time to be affected. It frequently happened that traverse lines had to be run before the triangulation points were available, and connection was made later as soon as the triangulator had placed his mark. At every stage the problem arose of doing as much work as possible so as to avoid subsequent delay, and to control it before any of it was actually employed. In this way many of the villages had to be traversed while the triangulators were at work in the same district; as soon as they had finished, the traverses were connected to the nearest triangulation points so that the Computation Office could compute and control them, in order to plot the points so determined on map-sheets for the chain-survey to use as soon as possible.

Each traverser prepared a statement of the work done in each village, giving the number of points placed, the length of lines traversed, the time taken, etc., together with a sketch of the network. The descriptive list of the points, the angle-sheets, and field-books were sent in to the Computation Office at Headquarters as soon as the work was done.

The average rate of work including journeys, walking over the ground, placing marks, corrections, etc., was about seven points per man per working day, or about half a square kilometre (119 feddans). As there are about 270 working days in the year, when the public holidays, leave, Fridays, etc., are deducted, the annual out-turn per traverser was about 130 square kilometres, or 321,360 feddans.

During 1899, work was pushed on in the province of Giza and also in Menufia, in order to give the triangulators time to complete their work in the Fayum, for it had become evident that the small staff available could with difficulty finish Fayum before it was required and that Menufia province must be surveyed without triangulation, but only with traverses as a control, on account of the necessity for keeping to the programme which had been laid down of re-assessing two provinces annually; by this means an earlier start could be made with the triangulation of Qaliubia and Daqahlia.

In 1900, all the traverse lines in Menufia province had been marked and observed and those in the Fayum were nearly finished by the end of the year. The rate of traverse work is mainly affected by the willingness of the villagers to preserve the marks put down; in

districts where they are not interfered with, work goes on rapidly, but in other places where they are removed or displaced it is much delayed. In no part of Egypt was interference with the marks carried to such an extent as in the Fayum province ; in all parts of the country a certain percentage of points are lost by accident or theft, but, in Fayum, fifteen and twenty marks would be missing from a single small village. The sheikhs of the village are shown the position of the marks, descriptive lists are supplied to them, signed undertakings are received that the marks shall be respected, but all were as ineffectual and worthless as those taken fifteen years before by the Cadastre of 1878–1888. Legal proceedings entailed much loss of time in witnesses attending to give evidence when they were urgently required in the field at their work, so, as the primary consideration was the rapid completion of the maps in order to admit of speedy re-assessment of land-tax, the only practical solution was to increase the average number of points per square kilometre so as to allow for probable losses. Even then, the loss of more important points necessitated repetition of parts of the work, and in the Fayum province enough work was done to traverse a province half as large again. This greatly delayed the extension of the traverse to Daqahlia and Qaliubia in 1901, where much triangulation was already completed, before the traversing of the villages could be commenced.

The persistent removal of traverse marks in the Fayum, as well as elsewhere, suggested that some advantage was likely to be gained by using a less conspicuous mark than a block of stone, and one which was less useful in building construction, in providing counterweights for the "shadufs" (bucket sweeps for raising water) and many other purposes ; moreover, as a mark over which a theodolite was to be centred, a roughly dressed stone 20 by 20 centimetres left much to be desired, and was a source of error which it would be well to eliminate as far as possible. In the year when traverse lines were first introduced and only three to four marks were fixed per square kilometre, the labour of transporting and placing these marks was slight and it was carried out by the villagers, who were glad to have the boundaries of their villages thereby defined, but, with the increase in the annual amount of work, and the greater number of points per square kilometre which were utilized, all transport and fixing of traverse marks was paid for, so that economy in this direction also prompted a reduction in the size

and weight of the mark. Short lengths of angle-iron were therefore adopted as being easy of transport, as affording a definite mark over which the theodolite could be centred, and, as being more easily identified if stolen when stamped with a special mark, than a rough-dressed stone. They were made of half-inch angle-iron, 0·60 metre long and were driven into the ground until only about five centimetres was left above the surface; their cost is L.E. 14 per 1,000. On the whole, they have answered very fairly well, though, here and there, they have been removed with considerable frequency in order that they might be forged into the rude agricultural implements used in the villages. Besides those which are intentionally removed, a certain number are lost, and this reaches its maximum in the basin lands where they may be covered up by the mud deposited by the annual flood, or are ploughed up when the ground is being tilled. In areas where perennial irrigation is practised, they last well enough, and will probably do so better when the inhabitants have grown accustomed to them and have realized their utility.

Their purpose was often misunderstood, and when one was placed near but not on a landowner's boundary he assumed that his limits had been wrongly recorded; the mark was therefore moved by him and placed on his boundary or was taken away altogether.

From 1907, marks indicating the point where the boundary lines of three or more villages met were set in masonry, as well as every third or fourth mark along the boundary of a province, since some time may elapse between the times at which two contiguous provinces are surveyed; in the meantime, landowners near parts of the boundary which are not defined by a natural feature, such as a canal or road, may encroach slightly on each other's land, and, without fixed points at short intervals it is often impossible to say whether a change which is found subsequently is due to such encroachment or to slight errors in the earlier survey.

As soon as the theodolite traverses were properly controlled by triangulation of satisfactory accuracy it became possible to lay down definitely the precision demanded in the form of a scale of maximum permissible errors. The permissible discrepancy between two measurements in the field was fixed at 1·0 per 1,000; while those allowed in linear and angular measurements are given in the following tables which are those in use in Computation office.

PERMISSIBLE ERROR IN LINEAR MEASUREMENTS.

Sum of the sides.	Maximum admissible error.		
	Good ground.	Average ground.	Bad ground.
m.	m.	m.	m.
200	0·32	0·39	0·45
400	0·49	0·60	0·69
600	0·65	0·79	0·92
800	0·80	0·98	1·13
1,000	0·95	1·16	1·34
1,500	1·31	1·61	1·86
2,000	1·67	2·05	2·36
2,500	2·03	2·48	2·88
3,000	2·39	2·92	3·38

PERMISSIBLE ERROR IN ANGULAR MEASUREMENTS.

No. of sides in traverse	2	4	6	8	10	15	20	25	30	35	40
Error in closure... ...	2′·1	3′·0	3′·7	4′ 2	4′·7	5′·8	6′·7	7′·5	8′·2	8′·9	9′·4

If these were exceeded the work was returned for correction.

It is not always possible to state precisely the true error in a carefully run line of traverse when it is compared with the triangulation points between which it lies, for the accepted position of each of these points is that which is the most probably correct in view of the various small discrepancies which have to be taken into consideration when the triangulation is computed. The second order triangulation having been corrected so as to be homogeneous, the third order and fourth order are similarly adjusted to the other and the result is a network of points of which the accepted positions differ by very small amounts from their true positions. But it is possible that a carefully run traverse may give the distance between any two neighbouring points even more accurately, and then the traverse work is altered to agree with the triangulation, thus introducing a small though practically inappreciable error. In this connection an examination of the traverse work by the test of triangulation may

make the former appear slightly less correct than it really is. This difficulty has been found to occur in the cadastral survey of Prussia and may easily happen where the traverse surveyors are skilful and work with great care.

Nevertheless a useful test may be made of the accuracy of the traverse work as finally accepted by comparing the distance between the triangulation points with the most direct line of traverse joining them. For this purpose a number of lines have been selected absolutely at random and the discrepancies found for them have been considered as fairly representing the average for the district. It is highly probable that the averages for the provinces are quite representative. A different selection for traverse lines in the province of Beni Suef * gave the discrepancy as 0·50 per thousand against 0·53 now found when the shortest traverse lines from point to point are utilized. The general conclusion is that the discrepancy of the traverse work approaches 1 in 1,800. Good chaining in Europe has a discrepancy of about 1 in 2,000 ; so that the work which has been done is very nearly equal to good European work in spite of the high rate of out-turn which was demanded.

THE ERROR IN LENGTH OF TRAVERSE LINES AS DETERMINED BY TRIANGULATION.

Province.	District.	Number of lines.	Mean error in length per 1,000.
Giza	El Ayat...	19	0·67
	Embaba	20	0·65
	El Saff	13	0·53
	El Giza	9	0·52
		Total 61	Mean 0.61
Fayum	Sennures	25	1·24
	Etsa	25	0·96
	El Fayum	22	0·72
		Total 72	Mean 0·99

* Survey Department Report, 1906.

THE ERROR IN LENGTH OF TRAVERSE LINES AS DETERMINED BY TRIANGULATION.

Continued.

Province.	District.	Number of lines.	Mean error in length per 1,000.
Qaliubia	Cairo Environs	18	0·60
	Nawa	25	0·63
	Tukh	24	0·61
	Qaliub	25	0·60
		Total 92	Mean 0·61
Daqahlia... ...	Mit Ghamr	25	0·44
	Simbellawein	25	0·82
	El Mansura	25	0·57
	Damietta	20	0·75
	Dekernes	23	0·47
	Aga	22	0·53
		Total 140	Mean 0·59
Qena	Nag Hamadi	25	0·59
	Esna	16	0·63
	Luxor	20	0·49
	Dishna	20	0·80
	Qena	20	0·84
	Qus	17	0·60
		Total 118	Mean 0·66
Aswan	El Derr...	25	0·39
	Edfu	21	0·50
	Aswan	22	0·60
		Total 68	Mean 0·50
Girga	Tahta	23	0·52
	Girga	24	0·43
	Baliana...	20	0·46
	Sohag	25	0·43
	Akhmim	20	0·51
		Total 112	Mean 0·47

THE ERROR IN LENGTH OF TRAVERSE LINES AS DETERMINED BY TRIANGULATION.

Continued.

Province.	District.	Number of lines.	Mean error in length per 1,000.
Assiut	Assiut	24	0·35
	Abu Tig...	25	0·44
	Manfalut	25	0·50
	El Badari	14	0·51
	Abnub	25	0·38
	Deirut	23	0·50
	Mallawi...	19	0·67
		Total 155	Mean 0·50
Minia	Maghagha	21	0·48
	Samalut	22	0·59
	El Feshn	17	0·64
	El Minia	23	0·42
	Beni Mazar	20	0·79
	Abu Qirqas	20	0·59
		Total 123	Mean 0·58
Beni Suef ...	Beni Suef	21	0·68
	El Wasta	21	0·42
	Biba	23	0·49
		Total 65	Mean 0·53

In comparing this with the results obtained in European countries, it is only fair to state that those who carried out the traversing had not been through a course of engineering and scientific instruction such as is given in polytechnic schools; but possessing at first but an elementary education, not always including a primary certificate, they were trained in the Department for this work and carried it out most creditably in the face of no inconsiderable difficulties. The short time which was available rendered it necessary to work at high pressure and the regulation method of procedure had often to be departed from. Main lines of traverse were to be run as directly as possible from one triangulation point to another, then subsidiary traverse lines were to be run from these along the village boundary and secondarily across the village, along canals, and whenever they were necessary in order to

divide up the area conveniently for chain survey. But at this time the village boundaries were shown on no plan, so that the traverse surveyor had to track the limits of each village with the aid of the village authorities; under these circumstances he usually had to deal with the authorities of three or four different villages in order to run his traverse line from one triangulation point to another. This involved much loss of time, and in practice it was usually necessary to traverse the boundary of each village and join such traverses as were nearest to the different triangulation points by short lengths of traverse. This did not greatly harm the traverse but often delayed the Computation Office, since traverses of villages could not be computed till the main traverse lines to the triangulation points had been computed. Other difficulties were due to the physical conditions under which the work was done; in Lower Egypt it was impossible either to measure or to sight along the lines when the "durra" * grew up and work was then confined to the neighbourhood of the village itself, the canal banks, etc.; in Upper Egypt some trouble was experienced by the traverse marks being sometimes covered up by the mud which was deposited in the irrigation basins from the flood water, while the areas sown with sugar-cane could not be traversed until the cane had been cut; these obstacles together with the impossibility of working in the basins during the Nile flood, viz., from August to November, greatly curtailed the working season, and though as much work as possible was done on banks and dykes it was very difficult to keep a sufficient area marked and traversed early enough for it to be computed and plotted by the time that the surveyors required the map-sheets for plotting the holdings in the field as they were measured up.

The theodolite traverse work had been originally organized in 1896 as a preliminary stage of the chain-survey and was directed from the same office. This arrangement continued until this year when a change became desirable. Second order and third order triangulation are now being regularly observed, and the traversing was closely connected with the latter of these; at the same time the detailed work of the chain-survey section has been increased and more supervision is therefore entailed. The traverse branch has, therefore, been transferred to the third and fourth order triangulation in 1908.

* Indian corn or millet.

Whereas at first engineers alone were employed on traversing, from 1901 onwards young surveyors were trained specially for the work, and were placed under engineers for supervision.

The cost of the work in different years and other statistical information is given in the following table for such provinces as have not already been dealt with on pages 213 and 214.

Province.	District.	Area in feddans.	Chainage in kilometres.	Kilometres chained per sq. kilometre.	Total number of points.	Average points per day.	Average points per sq. kilometre.	Cost per point.	Cost per sq. kilometre.
								MILLS.	L.E. M.
Aswan	Aswan	15,883	604·7	9·06	2,437	8·5	36·5	106	3·861
	Derr	16,024	910·7	13·53	3,826	6·6	56·8	140	7·956
	Edfu	43,217	888·0	4·89	3,428	8·8	18·9	106	2·009
	Total for Mudiria ...	75,124	2,403·4	—	9,691	—	—	—	—
	Mean „ „ ...	—	—	7·61	—	7·7	30·7	119	3·669
Qena	Dishna	61,029	860·9	3·35	2,915	7·3	11·4	138	1·570
	Esna	50,682	756·4	3·55	2,714	6·9	12·7	103	1·322
	Luxor	68,174	963·2	3·33	2,749	6·5	9·5	107	1·014
	Nag Hamadi	95,918	1,370·8	3·40	4,8[illegible]1	6·8	12·1	107	1 217
	Qena	49,[illegible]13	794·6	3·80	2,618	7·5	12·5	105	1·323
	Qus	62,440	996·8	3·80	3,439	9·2	13·1	88	1·151
	Total for Mudiria ...	388,556	5,742·7	—	19,306	—	—	—	—
	Mean „ „ ...	—	—	3·51	—	7·3	11·8	106	1·253
Girga ...	Akhmim	37,143	916·8	5·87	3,303	8·3	21·2	103	2·186
	Baliana...	74,126	1,213·2	3·90	3,066	4·1	9·8	163	1·606
	Girga	89,289	1,527·6	4·07	5,845	6·5	15·6	103	1·600
	Sohag	67,281	1,287·3	4·55	4,987	6·2	17·6	95	1·672
	Tahta	94,530	1,544·1	3·89	6,918	7·8	17·4	95	1·647
	Total for Mudiria ...	362,369	6,489·0	—	24,119	—	—	—	—
	Mean „ „ ...	—	—	4·26	—	6·4	15·8	106	1·687
Assiut ...	Abu Tig	61,452	1,200·1	4·64	4,305	6·5	16·6	110	1·830
	Assiut	57,584	1,126·3	4·65	4,020	6·8	16·6	98	1·636
	Badari	41,5[illegible]8	664·7	3·80	2,854	7·8	16·3	100	1·644
	Deirut	91,082	1,352·4	3·53	6,178	7·2	16·1	119	1·917
	Ebnub	62,527	859·2	3·24	3,574	6·7	13·6	85	1·159
	Mallawi	90,476	1,652·6	4·34	8,491	7·6	2[illegible]·3	105	2·341
	Manfalut	85,8[illegible]6	1,238·3	3·43	5,453	7·0	15·1	117	1·776
	Total for Mudiria ...	490,555	8,0[illegible]3·6	—	34,875	—	—	—	—
	Mean „ „ ...	—	—	3·92	—	7·1	16·9	107	1·321

Province.	District.	Area in feddans.	Chainage in kilometres.	Kilometres chained per sq. kilometre.	Total number of points.	Average points per day.	Average points per sq. kilometre.	Cost per point.	Cost per sq. kilometre.
								MILLS.	L.E. M.
Minia ...	Abu Qurqas	53,879	938·0	4·14	3,833	6·6	16·9	122	2·069
	Beni Mazar	94,623	1,479·0	3·72	6,293	5·9	15·8	122	1·924
	Feshn	61,411	928·2	3·59	3,822	8·0	14·8	92	1·359
	Minia	67,852	1,006·8	3·53	3,958	7·5	13·8	102	1·411
	Maghagha	73,617	891·3	2·88	3,540	10·3	11·4	90	1·032
	Samalut	85,560	1,424·1	3·96	5,663	8·6	15·7	102	1·606
	Total for Mudiria ...	436,942	6,667·4	—	27,109	—	—	—	—
	Mean „ „ ...	—	—	3·63	—	7·4	14·7	106	1·570
Beni Suef.	Beni Suef	100,190	1,268·2	3·01	5,064	5·9	12·0	131	1·582
	Biba	84,923	1,352·9	3·79	5,006	5·8	14·0	119	1·673
	Wasta	70,852	980·0	3·29	3,800	7·4	12·7	112	1·432
	Total for Mudiria ...	255,965	3,601·1	—	13,870	—	—	—	—
	Mean „ „ ...	—	—	3·35	—	6·2	12·9	122	1·571
Qaliubia ...	Dawahi Masr	17,330	244·6	3·4	934	4·0	12·8	—	—
	Nawa	73,048	924·9	3·0	2,994	6·0	9·7	076	743
	Qaliub	56,567	753·6	3·2	1,670	5·7	7·0	143	1·003
	Tukh	73,673	771·9	2·5	3,505	7·1	11·3	189	2·112
	Total for Mudiria ...	220,618	2,695·0	—	9,103	—	—	—	—
	Mean „ „ ...	—	—	2·9	—	6·0	9·8	138	1·322
Sharqia ...	Belbeis	104,539	1,434·3	3·3	5,398	5·9	12·3	125	1·540
	Faqus	245,191	2,242·2	2·2	8,037	6·0	7·8	112	1·112
	Hehia	72,120	1,104·1	3·6	4,626	5·4	15·3	152	2·324
	Kafr Saqr	141,154	1,687·1	2·8	7,278	5·0	12·3	170	2·087
	Minia el Qamh	78,720	1,332·2	4·0	7,003	5·1	21·2	153	3·250
	Zagazig...	211,346	2,117·2	2·4	7,790	6·5	8·8	135	1·191
	Total for Mudiria ...	853,070	9,917·1	—	40,132	—	—	—	—
	Mean „ „ ...	—	—	2·8	—	5·6	11·2	147	1·645
Daqahlia .	Aga	71,725	560·2	1·8	1,616	5·2	5·4	209	1·122
	Dekernes	205,210	1,094·4	1·3	3,788	4·9	4·3	278	1·222
	Faraskur	57,774	1,015·3	1·2	3,783	7·1	15·6	104	1·622
	Mansura	80,859	1,131·2	3·3	3,682	5·0	10·8	124	1·349
	Mit Ghamr	83,341	938·6	2·7	3,484	6·5	10·0	162	1·616
	Simbellawein	128,422	1,631·2	3·0	5,525	5·2	10·2	117	1·200
	Total for Mudiria ...	627,331	6,370·9	—	21,878	—	—	—	—
	Mean „ „ ...	—	—	2·4	—	5·6	8·3	158	1·312

CHAPTER XV.

COMPUTATION.

By Mr. J. I. Craig.

Introduction.

In 1898 it was realized that one of the essentials to improvement of the quality of the work was that the computation of the field observations should be taken out of the hands of the observers and entrusted to a central staff; in the following year this change was effected, and the nucleus of the present Computation Office formed. Its duties were at first limited to traverse work, for what triangulation existed had already been computed by the observers, but in 1900 computation of triangulation was added and in 1901 computation of geographical positions and projected co-ordinates. Area computations were introduced in 1902, but little more was possible after that, beyond gradually improving the quality of the computation, particularly the adjustment to consistency, until 1905, when pressure was slightly relieved in the triangulation section and it became feasible to improve the quality further, and 1907, when a similar improvement was introduced into traverse computation. Throughout the work, until quite recently, rate of output has been the determining factor. A definite area had to be surveyed each year and the best that could be done was to watch computations as carefully as possible, improving wherever possible, but never delaying. As an instance of the conditions under which some of the work had to be carried out, it may be mentioned that at one time in 1903, the observers of both orders of triangulation, the traverse engineers, and the detailed surveyors were working within sight of one another near Edfu in Aswan province. The average rate of work should have sufficed for the survey of about 600,000 feddans annually, but by 1898 heavy arrears had been accumulated, and the pressure in the following years was correspondingly increased, so much so that in 1905, for example, it was necessary to compute and plot points for the survey of 930,000 feddans. And not only were the conditions themselves sufficiently

exacting, but they were rendered more so by extraneous circumstances, such as the postponement of the triangulation of Girga province to take up that of Aswan. To enable work to be carried out under the most favourable circumstances, a notice of at least eighteen months would have been desirable in order that triangulation and traverse field-work and computation should proceed steadily, and maps be ready for the detailed survey in time, but this notice could not be given, for the ruling factor here was the time at which the Aswan Dam would be completed, and its early completion was the result of the unexpected occurrence of a series of low Nile floods.

The staff available for the calculations was almost entirely without training. A few of the older men had had a slight experience of the traverse computations, but so devoid of mathematical training of any sort beyond the simplest arithmetic were they, that no one possessed a knowledge of algebraic subtraction. On the other hand, they were readily taught to do one thing at a time and do it satisfactorily under supervision. It was clearly advisable, therefore, to carry out the principle of subdivision of labour to the fullest extent. Each computer received a certain class of work, and was kept doing that and that only, until possibly expansion allowed of his promotion to another class. Besides subdividing the labour, each man's task had to be made as simple and straightforward as possible, which was achieved mainly by reducing everything to a stereotyped system. Thus, for example, even in triangulation where the most skilled of the computers were employed, the method of least squares was adopted in adjusting the figures, not so much because the precision of the work necessitated its use, as that it furnished a mechanical method of obtaining a unique solution of the problem.

At the same time the necessity of control was never lost sight of. Wherever possible, computations were arranged so as to be self-checking, and when this could not be done, control by an independent method, or, failing that, by an independent computer, was introduced. The chief lesson of this part of the work is, perhaps, the absolute necessity for laying down from the first limits which must not be exceeded when adjusting errors of observation. These may be widened if necessary, but should never be omitted.

As has already been pointed out in other chapters, the conditions that have demanded rapid work in Egypt are not unlikely to recur

elsewhere, as other lands are developed, and however much different geographical conditions may alter the details of the work, it is probable that the broad principles will remain untouched. These demand :—

(1) the systematization of the work so that observations are received in one part, mechanically progress through the office, dropping out for amendment where the sifting process shows that they are inexact, and ultimately issuing in the form wanted by the workers on the detailed survey ;

(2) a careful system of control ;

(3) a fixed standard of precision not only in observation but also in computation.

Aids to Computation.—The books of mathematical tables employed have been the following :—

"New Mathematical Tables," by Peter Barlow, London, 1814. (Reprint in part, London, 1907).—This contains tables of squares, square roots, etc., of all numbers from 1 to 10,000, and has been found extremely useful for all work connected with calculation of mean and probable errors, and in certain parts of the base-line work.

"Tables de Calcul," par A. L. Crelle, Berlin, 1904.—This table of products of all numbers from 2×1 to 999×999 has been used chiefly in adjustment of the figures by least squares.

"Tables de Logarithmes à 7 décimales," par J. Dupuis, Paris, 1891.—This book of logarithms is in regular use for all triangulation and astronomical computations, and in computing co-ordinates of second order points.

"Tables de Logarithmes à 5 décimales," par J. Dupuis, Paris, 1904.—This has been used for much of the interpolation work, and for the computation of the successive geographical positions of trigonometrical points.

"Four-Figure Mathematical Tables," by J. T. Bottomley, London, 1904.—The tables of logarithms are hardly accurate enough for traverse computations. At one time they were used for checking these by

re-calculation of the lengths and bearings of the lines; but it was found that the methods described on p. 287 gave sufficient check, and this method was therefore abandoned. The lack of time prevented the use of five-figure tables.

"Computation Rules and Logarithms," by Silas W. Holman, New York, 1900.—The five-figure logarithms in this book have been recently taken into use. With the help of the tags supplied for fixing to each page, the tables can be entered with almost the same rapidity and much greater accuracy than four-figure tables.

"Thesaurus logarithmorum completus," von Georg Vega, Leipzig, 1894.—Occasionally used, when eight-figure logarithms seemed desirable.

"Formeln und Hülfstafeln für geographische Ortsbestimmungen," von Prof. Dr. Th. Albrecht, Leipzig, 1894

The tables of $W=\sqrt{1-e^2 \sin^2 \varphi}$, and some others, given here have been used in computing co-ordinates of trigonometrical points. The tables are based on Bessel's dimensions for the spheroid.

"Elements of Precise Surveying and Geodesy," by Mansfield Merriman, New York, 1899.—Tables are given in the appendix to facilitate the computation of the geographical positions of successive trigonometrical points. They are based on Clarke's (1866) elements of the spheroid. His linear dimensions are reduced to metres by the relation : **1 metre = 39·3700 English inches.**

This defines the American metre in terms of the inch, and through the comparison of the inch with the international metre,* in terms of the latter standard. From this comparison we have :—

1 congress metre = 0·99999713 international metre.

The logarithm of the factor is 9·9999988–10. Thus, all tables given in this book which involve the semi-diameter of the earth linearly may be expressed in terms of the international metre by subtracting one part in 400,000, or by subtracting 0·0000012 from the logarithms

"Les nouveaux appareils pour la mesure rapide des bases géodésiques," par Benoit et Guillaume, Paris, 1906.—The tables published

* "La convention du mètre." Paris, 1902, p. 101.

in this work are of the utmost use in computing base-measurements when the apparatus elaborated by the authors is employed.

"Opus Palatinum sinus- und cosinus-Tafeln von 10″ zu 10″," von Dr. W. Jordan, Hannover und Leipzig, 1897.—The value of the sine and cosine of the bearing of a traverse line can be taken from these tables without interpolation. They have been used throughout for the computation of the differences of latitude and the departures in the traverse computation.

"Traverse Tables," by Major-General J. T. Boileau, F.R.S., London, 1906.—This work has been used throughout in checking the computation of the differences of latitude and the departures in the calculations of the traverse.

Mechanical Aids.—All the multiplications required in the traverse computations and in calculating the area inside traverse polygons have been carried out with the Brunsviga computing machine. This has been most useful, but would be even more so if the wearing parts could be made of a harder material. Some eleven of these machines have been in use, but owing to wear of the parts, two or three of them are generally under repair at a time, owing to the heavy wear involved.

Additions are generally performed with the Comptometer, which has been much improved recently in the direction of reducing the thrust of the keys and lessening the force required to work it.

Fuller's spiral slide-rule and slide-rules of 25 and 50 centimetres length, of the ordinary pattern, have been occasionally employed for small multiplications. Warping of the wood from the excessive dryness of the air has led to a little trouble, but the extra friction of the slide caused in this way can generally be overcome by the application of graphite.

An abacus with 12 balls in each of the last two columns was designed as an aid in the addition of feddans and their subdivisions, qirats and sahms, but the computers in the local offices never became expert enough at its use to warrant its general adoption. It appears, however, to be well worth a serious trial where inexpert computers have to be employed.

Bases.

The base-lines of the Egyptian second order triangulation may be divided into those measured with the hundred-metre steel band, and those measured with the Jäderin bi-metallic wires.

The method of measurement in the two cases was essentially the same. A series of marks, at distances apart nearly equal to the length of the band or wires to be used, was carefully aligned between the terminal points of the base-line, or between subsidiary marks on the line of the base. The excess or defect of the distance between each consecutive pair of marks over or under the length of the band or wire was measured either by means of separate finely divided scales in the case of the steel band, or by scales attached to the apparatus, in the case of the wires. In the latter case, the scale divisions were engraved for a distance of ten centimetres on both sides of the fiducial points marking the extremities of the standardized length of the wire, and the fiducial point in the middle of each scale was numbered 10 and the graduations continued inwards to zero and outwards to 20. This plan was undoubtedly superior to that of using separate scales, for it abolished the possibility of recording wrongly the sign for the excess or defect at each end.

Since it was seldom possible to lay out a base which would be an exact multiple of the band or wire, it was usually necessary to measure the interval between the last of the equidistant marks and the terminal point of the base, which was done by a graduated steel tape.

Then the length of the base was found as the sum of the band- (or wire-) lengths plus the sum of the excesses of each subsection as measured by the scales plus the distance of the terminal from the last subsectional mark. This is the rough theory of base measurement, but in practice, various precautions, entailing various corrections, have to be adopted. Thus, the length of the band is not constant, but depends on the tension and the temperature; the subsectional points may not be on the same level surface, whereas the whole base-line is supposed to be so; and finally, even where corrections have been applied to give the resulting length of the base as if it had been measured on a level surface, this may not be the particular level-surface called sea-level, on which the triangulation operations are supposed to be conducted.

In the Seila base the corrections were somewhat complicated by the fact that the band rested on the ground and followed its bendings. No allowance could be made for the consequent shortening of the distance between the fiducial points, and it should be borne in mind that this base had probably a length assigned to it in excess of the true value.

The principal correction is that for temperature, and it was the most difficult to find exactly, when the band was used. The temperature used in the computations was the mean of the readings of two thermometers placed on the ground beside the tape when the latter rested on the ground, or swung in the air when, as at most of the bases, the tape was swung on supports so as to be clear of the ground everywhere.

In every case, the measurements with the tape were made in the morning about sunrise, and the evening about sunset; and there is a presumption that if the temperature used was in the one case too low, it would be too high in the other case, which would lead to a mean result not far from the truth.

If L_0 be the length of the tape at the temperature of standardization, t_0, and if α is the coefficient of thermal expansion of the material, then the length of the tape at temperature t is L, where

$$L = L_0 [1 + \alpha(t - t_0)], \text{ and } \Sigma L = \Sigma L_0 + \alpha L_0 \Sigma (t - t_0).$$

If t is the mean temperature during the measurement, and n is the number of subsections, then

$$\Sigma (t - t_0) = n (\bar{t} - t_0) \text{ and } \Sigma L = n [L_0 + \alpha L_0 (\bar{t} - t_0)].$$

The coefficient of thermal expansion, α, for the steel tape was never determined: neither the time nor the apparatus was available; and a value had to be assumed. That taken ultimately was $\alpha = 1{\cdot}17 \times 10^{-5}$ as a mean between values given by various authors, which ranged from $0{\cdot}97 \times 10^{-5}$ to $1{\cdot}25 \times 10^{-5}$.

Reduction to the Mean Level Surface of the Base.—For such differences of level as usually exist between subsections of base-lines, it may be assumed that the level-surfaces are all parallel. Hence the projection of the length of a subsection on any one of them may be considered the same as that on the mean level-surface of the base.

The correction for difference of level in the subsections is $-\frac{1}{2L}\Sigma h^2$

It is to be noted that h and L must here be expressed in the same units, even if they have been measured differently. Should the last subsectional mark and the terminal point of the base be at different levels, a separate correction must be applied, since we are not at liberty to assume that L is here the same constant.

In computing the base-lines h was always expressed in centimetres and the values of h^2 were taken from Barlow's tables.*

With the tape 2 L is 20,000 centimetres, so that the correction readily follows.

Reduction to Sea-Level.—Since triangulation is supposed to be conducted on the sea-level surface, the bases must be projected by normals through their extremities on to this surface.

The reduction to sea-level is — BH/R where B is the length of the base, H its altitude and R the mean radius of the earth.

In practice, it is customary to project all triangulation points by normals on to the sea-level surface, and for geodetic work, this is unexceptional; but in the case of triangulation executed for the purpose of a cadastral survey, it would appear to be more logical to project the points on to that level-surface which may be regarded as a mean for the area to be surveyed, or else to introduce a small correction for the general elevation of the region above sea-level when areas come to be computed. The magnitude of the correction will be 2 HA/R where H and R have the significations already assigned to them, and A is the area measured. An upper limit of 125 metres may be placed to the level of cultivated lands in Egypt, and for this extreme case the correction would amount to about one part in 50,000 of the length, while for the greater part of the country it will not exceed one part in 100,000, so that it may be entirely neglected. For areas measured on high table-lands, however, the correction might become significant. In Egypt, accordingly, this correction has been generally neglected.

Correction for Tension.—When the tape is laid on the ground, the only effect of tension is to increase the length by stretching; the correction to the length of the tape on this account may be called the stretch-

* "New Mathematical Tables," by PETER BARLOW, London, 1814.

correction and is proportional to the length. When the tape is slung freely on supports a correction must be applied for the effect of sag. This may be called the sag-correction and is proportional to the length, and the square of the weight directly, and to the squares of the number of arcs in which the tape hangs and of the tension inversely. The effect of the first is to make the tape appear too long and distances measured with it too short, and of the second, the reverse. Consequently the first correction is additive and the second subtractive. The combined correction may be written in the form $aT - b\,T^2$ where T is the tension in kilogrammes weight and a and b are constants that must be determined for each tape, or wire. They were determined by calculation with mean values of the densities and moduli of extension for all bases measured before April 1904; the corrections for tension were determined experimentally for the wires used at Roda; and after that the tape and wires were used at the tensions of standardization, so that no correction was necessary on this account.

Bases Measured with 100-metre Steel Tape: Seila Base.—The 100 metre tape was used for the measurement of this base, and was specially standardized before the work.

This first value of the tape length was only used for the triangulation of the Fayum. The standardized length of the tape laid flat on the ground was found to be 100·0547 metres at 16°·7 C. and under no tension. By experiment at Giza, it was found that corrections as follows had to be applied to take account of the actual manner of using the tape on Seila base (see p. 179):—

Tension.	Temperature.	Special correction.	Value of tape length to be used in computation.
12 kg.	16°·7 C.	+ 1·24 mm.	100·0559 metres.
15 kg.	16°·7 C.	+ 4·56 ,,	100·0593 ,,

In 1903, after the arrival of the Jäderin wires, with a view to expressing the triangulation in terms of one unit, the 100-metre tape was compared against wire 2 on the 100-metre asphalt base at Giza. Particulars of this measurement have been given on page 154.

The distances between the sectional marks of the base were compared with the length of the tape by means of two fine ivory scales, one divided in millimetres, the other in $\frac{1}{1,500}$ of a metre. The readings on the latter had to be reduced by one-third to get millimetres. The following tables exhibit the various procedures employed:—

Collection of the Readings.

Section.	Rear.			Front as observed.			Front reduced to cm.		Tension.
	Temp.	Reading.		Temp.	Reading.		Reading.		
		+	—		+	—	+	—	
	°C.	cm.	cm.	°C.	cm.	cm.	cm.	cm.	kilog.
1 - 2	32·0	0·10	—	31·6	3·55	—	2·37	—	12
	28·5	1·67	—	28·7	1·75	—	1·17	—	12
	35·7	—	0·12	35·2	2·10	—	1·40	—	15
	—	0·44	—	29·7	3·60	—	2·40	—	15
2 - 3	31·8	—	0·02	31·6	2·53	—	1·69	—	12
	28·5	1·04	—	28·7	—	0·98	—	0·65	12
	35·6	1·23	—	35·2	—	3·80	—	2·53	15
	—	1·27	—	29·7	—	2·30	—	1·53	15

Computation of the Corrected Sums of Readings.

Section.	Mean temperature. °C.	Sum of readings. cm.		Temperature correction. cm.	Sum of readings corrected for temperature. cm.	
		+	—		+	—
1 - 2	31·8	2·47	—	+ 1·767	4·24	—
	28·6	2·84	—	1 392	4·23	—
	35·4	1·28	—	2·188	3·47	—
	29·7	2·84	—	1·521	4·36	—
2 - 3	31·7	1·67	—	1·755	3·43	—
	28·6	0·39	—	1·392	1·78	—
	35·4	—	1·30	2·188	0·89	—
	29·7	—	0·26	1·521	1·26	—

The readings, temperatures and tensions were first collected on one form, and the readings on the front scale (1 : 1,500-metre) reduced to centimetres. The mean temperatures and the sums of the front and rear readings, taken from the last form, were collected on another on which the temperature correction for the excess temperature above 16°·7 C., at the rate of 0·117 centimetre per degree centigrade for each length of the tape, was also entered. When this was added to the sum of the readings, the result gave the readings corrected to the tape length at 16°·7 C. The corrected sums of the readings were then collected by segments, as in the following table and totalled. This was done because it was intended to check the segments of the base by angular measurements, but time did not permit of this being carried out.

SEGMENT I. — SUM OF CORRECTED READINGS.

Section.	1st measurement.	2nd measurement.	3rd measurement.	4th measurement.
	cm.	cm.	cm.	cm.
1 - 2	+ 4·24	+ 4·23	+ 3·47	+ 4·36
2 - 3	3·43	+ 1·78	+ 0·89	+ 1·26
3 - 4	− 0·04	− 0·11	− 0·72	− 0·42
4 - 5	+ 11·46	+ 10·11	+ 9·75	+ 10·05
5 - 6	+ 0·13	+ 0·23	− 0·51	− 0·19
6 - 7	+ 2·40	+ 2·21	+ 1·53	+ 1·84
7 - 8	+ 2·68	+ 2·55	+ 1·89	+ 2·27
Totals...	+ 24·30	+ 21·00	+ 16·30	+ 19·17
Special correction 7 × (T-100 m.) from table p. 235	+ 39·13	+ 39·13	+ 41·51	+ 41·51
	63·43	60·13	57·81	60·68

General mean 60·51 cm.
Length of segment I = 700·6051 metres.

The correction for error of level was made, once for all, at the end of the computations.

In the same way, the lengths of the other three segments were found, and the length of the whole base resulted :—

Length of segment	I	700·6051	metres
,, ,, ,,	II	700·5947	,,
,, ,, ,,	III	700·4549	,,
,, ,, ,,	IV	800·6575	,,
	Base	2902·3122	
Correction for level		—0·0089	
		2902·3033	

This value depends ultimately on the Stockholm base-unit, and on the assumption that the 50-metre wire had not altered between 1900, the date of standardization, and 1903, the date of comparison.

The difference between this value and that already given on page 180 is due to the difference in standardization, as the other, which was used for the Cadastre, depends on comparisons with a standard metre at Giza.

Tema.—The next base, in point of time, to be measured with the steel tape was that of Tema. The method adopted at Tema was essentially the same as at Seila, except that the partial suspension over triangular blocks of wood was abandoned, and free suspension over such blocks, or over well-greased iron spurs was adopted. Owing to the conformation of the ground, it was more expedient to place these supports at unequal than at equal intervals, although the computation was thereby somewhat increased.

With the help of Barlow's tables of squares, cubes, etc., the total sag correction per section was easily found. The method of computation was similar to that adopted for Seila. The following were the results for the different sections :—

SECTION I.

Six times the length of the standardized tape (100·02908 metres) + the corrections shown in the table, in metres:—

	1st measurement.	2nd measurement.	3rd measurement.	4th measurement.
Scale readings	+0·2746	+0·3057	+0·2955	+0·1473
Temperature correction	+0·0632	+0·0540	+0·0498	+0·0744
Sag correction	−0·3677	−0·3677	−0·3677	−0·2354
Level correction	−0·0183	−0·0183	−0·0183	−0·0183
Stretch correction..	+0·0389	+0·0389	+0·0389	+0·0487
Total correction ...	−0·0093	+0·0126	−0·0018	+0·0167
6 times tape-length = 600 metres	+0·1745	+0·1745	+0·1745	+0·1745
Length of section I, 600 m.	+0·1652	+0·1871	+0·1727	+0·1912
„ „ II, 800 „	−0·1057	−0·1278	−0·0680	−0·0888
„ „ III, 700 „	−0·1270	−0·1159	−0·1232	−0·1251
„ „ IV, 700 „	+0·3113	+0·3236	+0·3232	+0·3249
Total length of the base, 2,800 m.	+0·2438	+0·2670	+0·3047	+0·3022

The general mean gives: Length of Tema base = 2,800·2793 metres.

The unit is the metre of the Stockholm base. The probable error deduced from the agreement of the measurements of each section is ± 14·7 millimetres or 5·2 parts per million.

Addendan.—This was the most southerly base measured with the 100-metre tape. The measurement was executed in the same way as that of Tema, and the computation was carried out on similar lines. The conformation of the ground was more favourable, and the

supports of the tape were placed at approximately equal distances, but as a precaution, these distances were measured and the calculation of the sag effect made from the usual formula as at Tema. There were only two sections here, and each was measured twice from north to south, and twice in the reverse direction. At each measurement three readings of the scales were taken. The final length of the base is, therefore, the result of twelve sets of independent readings.

The computations for the two sections gave the following results:

SECTION I.

	1st measurement.	2nd measurement.	3rd measurement.	4th measurement.
Sum of scale readings...	+0·8622	+0·6435	+0·8325	+0·6257
Temperature correction	+0·0546	+0·0538	+0·0778	+0·0779
Stretch correction	+0·0526	+0·0658	+0·0526	+0·0658
Sag correction	−0·6688	−0·4280	−0·6688	−0·4280
Level correction	−0·0375	−0·0375	−0·0375	−0·0375
Sum	+0·2632	+0·2976	+0·2567	+0·3039
10 × (Tape—100 metres)	+0·2908	+0·2908	+0·2908	+0·2908
Length of section = 1,000 m.+	0·5540	0·5884	0·5475	0·5947

Mean length of section I 1,000·5712 metres.
" " " II 1,000·6464 "

Length of the base 2,001·2176 metres.

The probable error deduced from the discrepancies of the sections was ± 0·0092 m. or 4·5 parts per million.

Dakka.—This base also was measured with the 100-metre tape in conditions somewhat similar to those at Addendan.

There were three sections and each was measured once in each direction. Three readings were taken at each measurement. At the

south end, the last sectional mark overshot the base terminal by 2·2858 metres.

The final results were :—

	Section I.		Section II.		Section III.	
	1	2	1	2	1	2
	m.	m.	m.	m.	m.	m.
Sum of the scale readings	+1·0285	+0·5839	+1·1186	+0·5798	+1·3977	+0·8995
Temperature correction ...	−0·0068	+0·0211	+0·0337	+0·0590	+0·0253	+0·0548
Stretch correction ...	+0·0344	+0·0584	+0·0344	+0·0584	+0·0344	+0·0584
Sag correction	−0·9259	−0·4060	−0·9259	−0·4060	−0·9259	−0·4060
Level correction ...	−0·1667	−0·1667	−0·1137	−0·1137	−0·1375	−0·1375
Sum	−0·0365	+0·0907	+0·1471	+0·1775	+0·3940	+0·4692
Means...	+0·0271		+0·1623		+0·4316	

Tape × 27 =	2,700·7851 metres.
Corrections as above.	+0·0271
	+0·1623
	+0·4316
	2,701·4061
Less excess at south end...	−2·2858
Base	2,699·1203

The precision was estimated by considering the respective sums of the first, second and third readings for each section as giving three independent measurements of the section. There were thus in all six independent measurements of each section.

The probable errors were found to be as follows :—

Section	I	+ 0·0191 m.
,,	II	+ 0·0047 ,,
,,	III	+ 0·0117 ,,
Whole base	... ...	+ 0·0229 ,, or 8·5 parts per million.

Khattara.—This base was measured under similar conditions to those of Dakka and Addendan, and the method of computation was substantially the same. The base was measured in five pieces, called in order from north to south B–X, X–Y, Y-Z, Z–XXV, and XXV-A. The first three sections were approximately 700 metres each, the fourth 400 metres and the last piece about 50 metres. Tension was applied by a 10-kilogramme weight slung over a frictionless pulley at one end, and its uniformity was measured with a spring balance at the other and the indications of the latter were employed in the computation. An examination of the differences shows that the spring balance recorded an average tension less by 0·22 kilogramme than that of the weight. The effect of this difference would be to increase the sag correction in the ratio $\left(\frac{10}{10-0\cdot22}\right)^2$ or by the fraction 0·044. The average sag correction was about 70 centimetres per 700 metres or 250 centimetres for the whole base, and 0·044 of this amounts to 11 centimetres. The difference in the stretch correction amounts to 0·24 centimetres or on the two together to 10·8 centimetres. This is on the assumption that the tension measured by the spring balance was the tension throughout the tape. If we assume that the tension at the weight end was 10·0 kilogrammes and at the other end 9·78 kilogrammes, and that the difference represents the effect of friction at the bearings of the tape, then the change of the whole correction for sag and stretch would amount to about half the above figure or 5·4 centimetres and the value of the base derived below might on this account be too small by that amount. This possible uncertainty of the correction for tension with a heavy tape is a strong argument for the use of wires, which are comparatively much lighter, and accordingly may be used without intermediate supports.

The results for the first section as a type were as follows :—

SECTION B—X.

	N—S				S—N			
	1	2	3	4	1	2	3	4
Sum of scale readings	+ 0·4247	+ 0·4447	+ 0·6008	+ 0·5955	+ 0·4032	+ 0·3927	+ 0·6650	+ 0·6914
Temperature correction	+ 0·0226	+ 0·0226	− 0·0687	− 0·0687	+ 0·0271	+ 0·0271	− 0·0903	− 0·0903
Stretch correction	+ 0·0310	+ 0·0309	+ 0·0306	+ 0·0307	+ 0·0308	+ 0·0312	+ 0·0295	+ 0·0296
Sag correction	− 0·6624	− 0·6668	− 0·6798	− 0·6737	− 0·6756	− 0·6546	− 0·7328	− 0·7250
Level correction..	− 0·1372	− 0·1372	− 0·1372	− 0·1372	− 0·1372	− 0·1372	− 0·1372	− 0·1372
Sums	− 0·3213	− 0·3058	− 0·2543	− 0·2534	− 0·3517	− 0·3408	− 0·2658	− 0·2315
7 × (Tape-length − 100 m.)... =	+ 0·2036	+ 0·2036	+ 0·2036	+ 0·2036	+ 0·2036	+ 0·2036	+ 0·2036	+ 0·2036
Section = 700 m.	− 0·1177	− 0·1022	− 0·0507	− 0·0498	− 0·1481	− 0·1372	− 0·0622	− 0·0279

The corrected length of the base was 2,549·8888 metres.

The probable error was calculated from the discrepancies of the eight independent values of each section. It is ± 0·0135 metre or 5·5 parts in a million.

Bases measured with the Jäderin Wires.—In using the wires Professor Jäderin recommends that a fixed tension should be employed, but it was decided that there would be a gain of time on the whole if the field party did not attempt to measure at one uniform tension, but simply recorded the tensions at which the measurements were made. Consequently one of the observers watched the spring balance and recorded the tension indicated at the instant the signal to read was given. For similar reasons, it was decided not to try to bring one fiducial mark of the wire to coincidence with the mark on the tripod head, but simply to read the scales at both ends simultaneously by signal, and to shift the wires slightly between each reading.

The employment of this method necessitated the introduction of corrections for tension, of the form $a\,T - b/T^2$. In all the computations with the 50-metre wires before Roda the following values were used :—

Wire.		a.	b.	Length of wire at tension T and 14 °C.
2 ...	Steel	0·1130	172·0	5002·58 cm. $+ aT - b/T^2$
3 ...	Brass... ...	0·2532	179·2	5000·33 cm. $+ aT - b/T^2$

These values were obtained from measurement of the thickness of the wires combined with assumed values of the densities of steel and brass, and of Young's modulus for each material. Both the density and this coefficient of elasticity may vary within wide limits and the values used may be subject to considerable error. In consequence of this, when the 25-metre wires were used at Roda they were standardized for tension. With the values so obtained it was possible on certain assumptions to compute other values for the 50-metre wires, and when this is done it appears that the values given above are in fair agreement with those deduced (see p. 249), but still suscept-

ible of further improvement. A recomputation of the bases has not, however, been made with these latest data for the 50-metre wires, since it has now been decided to undertake a first order triangulation, the bases of which will supersede those of the present topographical and cadastral second order work.

Moqattam.—This was the first base measured with the Jäderin wires. The method of computation was similar to that adopted for Seila where the 100-metre tape was employed, except that the temperature was deduced from a comparison between the measurements with wire 2 and those with wire 3.

The scale readings at each end were added together and a correction for tension applied as in the table below. This tension correction was based on the values $a = 0{\cdot}253$, $b = 179{\cdot}2$ for the brass wire, and $a = 0{\cdot}1130$, $b = 172{\cdot}0$ for the steel wire.

MOQATTAM BASE-LINE.

Section A-B. Part I.

Wire.	Readings.			Tension.		Corrected Readings.	
	Front.	Rear.	Sum.	Reading.	Correction.		Means.
	cm.	cm.	cm.	kg.	cm.	cm.	cm.
Steel, forward	11·23	10·23	21·46	8·2	+0·84	22·30	22·328
	11·28	10·20	21·48	8·2		22·32	
	11·30	10·21	21·51	8·2		22·35	
	11·30	10·20	21·50	8·2		22·34	
Brass, forward	12·11	9·80	21·91	8·2	−0·26	21·65	21·710
	12·15	9·80	21·95	8·2		21·69	
	12·15	9·80	21·95	8·2		21·69	
	12·27	9·80	22·07	8·2		21·81	
Steel, back	12·50	9·02	21·52	14·50	+3·29	24·81	24·742
	12·59	8·93	21·52	14·30	+3·24	24·76	
	12·60	8·89	21·49	14·35	+3·26	24·75	
	12·60	8·81	21·41	14·30	+3·24	24·65	
Brass, back	11·80	10·38	22·18	11·05	+1·66	23·84	23·885
	12·01	10·21	22·22	11·05		23·88	
	12·30	10·00	22·30	11·05		23·96	
	12·48	9·72	22·20	11·05		23·86	

The figures in the last column were then collected as below:—

SECTION A-B.

PART.	FORWARD.		BACK.	
	Steel.	Brass.	Steel.	Brass.
	cm.	cm.	cm.	cm.
1...	22·328	21·710	24·742	23·885
2...	27·450	24·760	16·123	15·413
3...	23·963	23·330	27·633	27·063
4...	15·523	14·895	23·915	63·433
5...	24·248	23·502	20·500	19·790
6...	24·833	24·162	20·133	19·353
7...	22·348	21·557	26·505	25·725
8...	22·815	22·032	21·898	21·083
9...	26·955	26·350	28·[illegible]90	27·240
10...	20·665	19·835	23·283	22·525
11...	30·065	29·392	26·505	25·632
12...	15·903	14·850	20·288	19·507
13...	25·648	25·035	19·900	19·085
14...	17·855	17·177	26·200	25·555
15...	29·665	29·070	28·923	28·323
16...	29·283	28·672	14·895	14·182
17...	25·115	23·722	30·570	29·902
18...	17·800	17·215	21·140	20·402
19...	18·725	18·167	16·973	16·347
20...	52·820	25·452	25·205	24·462
Sum 1,000 m. +	67·007	50·885	63·421	48·907

Then the differences 67·007 — 50·885 or 16·122 centimetres, and 63·421 — 48·907 or 14·514 centimetres, must be the differences between the expansion of 1,000 metres of steel wire and the same length of brass

wire. The difference on 1,000 metres per 1° C. is 0·75 centimetre. Hence the above differences correspond to rises of temperature amounting to 21°·496 for the forward measurement. The corrections for temperature are therefore $+ 100{,}000 \times 10^{-5} \times 21{\cdot}496$ centimetres, and $100{,}000 \times 1{\cdot}75 \times 10^{-5} \times 21{\cdot}496$ centimetres, or + 21·496 and 37·618 centimetres respectively. In the same way the corrections for the back measurement were found to be + 3·33 and 5·83 centimetres. We have thus the following lengths for the first section :—

	Forward.		Back.	
	Steel.	Brass.	Steel.	Brass.
	m.	m.	m.	m.
Sum as above 1,000 m.... ... +	0·67007	0·50885	0·63421	0·48907
Temperature correction, ... +	0·21496	0·37618	0·19356	0·33873
Corrected length 1,000 m. ... +	0·8850	0·8850	0·8278	0·8278
Level correction. ... ... −	0·3545	—	0·3377	—
Reduction to ground marks ... −	0·5142	—	0·4870	—
Length of section 1,000 m. ... +	0·0163	—	0·0031	—

In the same way the lengths of the other sections were found and the following table compiled : —

Section.	Forward.	Back.
	m.	m.
A—B	1,000·0163	1,000·0031
B—C	1,000·5592	1,000·4424
C—D	1,000·3908	1,000·3691
D—E	389·4292	389·4229
Length of the base...	3,390·3955	3,390·2375

Mean ... ... 3,390·3166 metres.
Reduction to sea-level ... ... − 0·0180

3,390·299 metres.

The value actually employed for the Cadastre was 0·59 metre less, owing to the fact that the constants were determined indirectly and were considerably in error compared with the later values, which,

without doubt, were the more correct. When the triangulation was being revised for topographical purposes, the length of the base was recalculated with the improved data as above. From the agreement between the observed lengths of the Tel el Kebir and Seila bases and the values computed through the triangulation, this is certainly better than the value for this base used for the Cadastre.

Gebelein.—This was the next base measured with the wires. It was divided into two sections of about 1,253 and 1,052 metres respectively. The equations containing the tension corrections were : —

$$W_s = 5{,}002{\cdot}47 \text{ cm.} + 0{\cdot}1130\ T - 172/T^2$$
$$W_b = 5{,}000{\cdot}33 \text{ cm.} + 0{\cdot}2532\ T - 179{\cdot}2/T^2$$

where W_s and W_b are the lengths of the two wires at temperature 14° C. Each section was measured twice. The thermal coefficients $\beta = 1{\cdot}75 \times 10^{-5}$ and $\alpha = 1{\cdot}00 \times 10^{-5}$ were used, so that the difference of expansion on 50 metres was $0{\cdot}75 \times 10^{-5} \times 5{,}000$ centimetres per degree centigrade, or 0·0375 centimetre per degree centigrade.

For Section I, we have the following :—

SECTION I.

	Forward.		Back.	
	Steel wire.	Brass wire.	Steel wire.	Brass wire.
Mean reading corrected for tension ...	1·4821 cm.	3·9125 cm.	4·2252 cm.	3·4508 cm.
Difference	0·5696 cm.		0·7744 cm.	
$t - 14$	15°·190 C.		20°·6507 C.	
Temperature correction	+ 0·7595 cm.	+ 1·3291 cm.	+ 1·0325 cm.	+ 1·8069 cm.
Mean reading corrected	5·2416 cm.	5·2416 cm.	5·2577 cm.	5·2577 cm
Mean distance between tripods	50·052416 metres		50·052577 metres	
Length of 25 such intervals	1251·3104	,,	1251·3144	,,
Reduction to the ground marks	+ 1·5267	,,	+ 1·4948	,,
Distance between ground marks	1252·8371	metres	1252·8092	metres
Level correction (tripods)	− 0·0286	,,	− 0·0260	,,
Horizontal length of the section	1252·8085	metres	1252·7832	metres
Probable error...	0·0084 metres			

Length of the base ... ... 2304·6856 metres.

The probable error is ± 0·0085 metres, or 3·7 parts per million.

Ambir.—The next base after Gebelein to be measured with the wires was Ambir. It was in two sections and the computation was similar to that of Gebelein. The summarized results are given on page 185. The constants used were the same as for Gebelein.

Roda.—Following Ambir, Roda base was next measured with the wires, but owing to the accidental breakage of wire No. 3 after 550 metres had been measured, the 25-metre wires were employed for the rest of the work both forward and back. Although there was a loss of time in this way, it is probable that there was a considerable gain in accuracy. As new wires were brought into use, they were properly standardized for tension before the computations were undertaken. There is little doubt that the tensions of 8 kilogrammes that had been used on one measurement at the three preceding bases was too low for 50-metre wires and that at least 12 to 15 should have been employed.

The standardization of the wires for tension was done by Mr. E. M. Dowson and the writer at Giza in the grounds of the Department. Two tripods were put up, 25 metres apart, under a balcony on the north side of the building, where the apparatus was well sheltered from radiation, and comparisons of the fixed distance between the two tripods and the length first of wire 1 and then of wire 4 were made with tensions varying by half-kilogrammes from 7·5 to 14 kilogrammes.

As the result of the measurement the following table giving the constants was obtained :—

Wire.	Material.	Value of		Length at tension T * and temperature of standardization.
		a.	*b.*	
1	Steel	0·05731	24·187	$2{,}500{\cdot}88 + a\,T - b/T^2$
2	..	0·1146	193·496	$5{,}002{\cdot}54 + a\,T - b/T^2$
3	Brass	0·2444	172·000	$5{,}000{\cdot}25 + a\,T - b/T^2$
4	..	0·1222	21·625	$2{,}500{\cdot}04 + a\,T - b/T^2$

* See p. 155.

After the details given of the computation of the other bases, it is unnecessary to do more than refer to the results obtained for Roda. The first section was measured with the 50-metre wires, the next eight with the 25-metre wires, and the last on the 20-metre tape.

The probable error was the smallest obtained in the base-line work and for this there are several reasons. First, as the result of the experience gained on the earlier bases, improvements in the method of suspending the wire had been introduced, and the tension was now applied through cords supporting lead weights and passing over pulleys on ball-bearings to remove friction. Secondly, the observers had benefited by the experience of the previous bases. Thirdly, the wires were properly standardized for tension, which undoubtedly was the most uncertain part of the earlier measurements. Further, the possibilities of the method had been better realized, and it was seen that, given the necessary carefulness, results of the highest precision might be attained, and the fact that the length of this base was not wanted with quite the same urgency as the others had been, admitted of sufficient time being devoted to the work. It is interesting to note that the estimates of the probable error of a base-line of about this length (± 2·0 millimetres) derived from the results of the tension standardization, were confirmed by the figures obtained in the field (± 1·7 millimetres).

Feshn.—In measuring this base, the wires were employed at the tension of standardization, 10 kilogrammes. Consequently, there was no need of applying a tension correction. Otherwise the computation was similar to that of the other bases measured with wires, and particulars need not be given here.

Tel el Kebir.—The methods of measurement and computation were similar to those of Feshn, except that in the second measurement, the whole base was measured in one part. There are thus only two independent measurements of the whole base.

There is nothing calling for special remark in the computation of the remaining bases.

Reduction of the Angular Observations.

Before proceeding to details about the methods adopted for the reduction of the angular observations, it may be desirable to recall the errors to which such observations are liable, and the manner of eliminating them.

A pointing with a theodolite is subject to the following errors:

1.—Error of collimation;
2.—Error due to dislevelment;
3.—Error due to eccentricity of the divided circle;
4.—Error of the circle divisions;
5.—Systematic personal error of the observer;
6.—Other small accidental and unsystematic errors.

These are eliminated in the following ways:

The error of collimation, by reversal of the face of the instrument.

The level error, by reversing the instrument in azimuth; or the two together, by reversal in altitude combined with reversal in azimuth. The level error is practically negligible except for stations at a considerable angular altitude above the point of observation, so that the double reversal, in both altitude and azimuth, is, in most triangulation work, simply a convenient method of eliminating the error of collimation. In the Nile Valley, where stations are seldom at an angular altitude of more than one degree, the error of collimation is the same for all pointings, and disappears from the angles.

The error of eccentricity, by reading two verniers or microscopes diametrically opposite.

Circle errors, as far as possible, by changing the zero systematically.

Systematic personal errors consist chiefly in error of pointing on the mark, error of bisecting the divisions of the circle by the micrometer hairs, and error of estimating the subdivisions on the micrometer head. So long as they are systematic and constant, they cannot be eliminated from the pointing, but this is of no consequence since they are then the same for both pointings, and the angle, which is the difference between the readings for the two pointings, will be unaffected.

There remain the accidental errors, which can only be minimized by due carefulness on the part of the observer, and by increasing the number of observations.

It is worth while remembering that when an operation is reversed to get rid of some error, the error may be found. Thus the error of collimation may be found from a comparison of the pointings observed with the instrument face-right with those observed when it is reversed; the eccentricity may be found by comparing the readings made with micrometer A with those made with B; the errors of division of the circle may be found by comparing the values of angles obtained on different zeros; and finally a measure of the excellence of the instrument and the carefulness of the observer may be deduced from the uniformity of the results obtained for these constants.

This control on the precision of the theodolite observations by computing the instrumental errors of course requires time, and it is only since the rate of work demanded for the cadastral survey has been lessened that it has become possible to apply it as a systematic part of the computation; but now that this is done, the results suggest the utility of never neglecting it. In this way a series of bad observations in Beheira was traced to a wobble of the vertical axis of the instrument; and a discussion of the circle errors of some of the theodolites has given instructive results, which have been confirmed by actual measurement of the circle errors at Helwan Observatory.*

In the observations for the angles of the second order triangulation each angle was derived as the difference of pointings to two stations, each pointing being made with the instrument face-right and face-left, and on six different zeros—0°, 30°, 60°, 90°, 120° and 150°—and the angles were read on the circle by two micrometers. To eliminate twist of the instrument or station, as far as possible, the pointings to stations were made successively clockwise and counter-clockwise. As far as possible, every station was sighted on every arc, but where this could not be done, owing to haze or other reasons, a supplementary set for the missing signal was observed. From each set of observations, it is thus possible to obtain twenty-four values of each angle, but these are not all independent. They have to be combined in pairs to eliminate errors of eccentricity, and this reduces them to twelve. But even these are not independent, for they contain errors of graduation of the circle. If the latter are known they can be applied as corrections, and the twelve different values for each angle will then

* B. F. E. Keeling, "Cairo Scientific Journal." 1908, Vol. II, p. 149.

contain none but accidental errors, and may be used to find its weight.

In the second order triangulation the circle errors of the different theodolites were never determined, but since theory, in agreement with practice, shows that these errors can be reduced to a negligible quantity by taking the mean of readings on different zeros, it was considered that the mean of the twelve values gave the true value of the angle. The difference of the various angles from this mean could not be considered accidental errors, since they contained the errors of division of the circle. It was decided, therefore, that weights should not be deduced from these discrepancies by finding their mean square, and after due consideration it was decided to assign equal weights to all angles. This practice has been adhered to throughout the reduction and adjustment of all angular observations. That the neglect of the theoretical weights was not an unjustifiable procedure, may be gathered from the fact that weights ranging from a hundred to unity would have resulted from the treatment of the twelve different values of the angles as independent, and when one remembers the fundamental meaning of weight in observational work, it is quite certain that no single set of angles was equivalent to a hundred sets of other angles observed with ordinary care.

The angles were booked as read in the field in special note-books, and were copied in ink on to angle-sheets adapted from those in use in the Survey of India (see page 254), where part of the computation of the angles at station B7 is shown), and were then sent to the Computation Office to be dealt with.

The method of computing the angles was in general as follows:

1. For each arc, the mean of the four micrometer readings for each signal (two face-right and two face-left), was taken and written in the column "mean."

No. 1 Party, Beheira, Trigonometrical Section.

Angles taken at B7 Station with 8-inch Theodolite No. 466. Date 27.1.1907.

Object.		Face.	Microscope Readings. A			Microscope Readings. B		Mean.			Angles.			Angles on different arcs collected.
			°	′	″	′	″	°	′	″	°	′	″	
Arc I.	G3	R	0	4	51	4	35	0	4	51·0				
		L		5	19	4	39				58	34	47·1	
	G2	R	58	39	11	39	12	58	39	38·1				Angle G3-G2.
		L		40	1·5	39	38				69	33	17·9	
	B6	R	158	13	11	12	32	128	12	56·0				58° 34′ 47″·1
		L		13	8	12	53				164	4	13·5	41 ·9
	B8	R	292	17	5	16	54	292	17	09·5				49 ·2
		L		17	36	17	3				67	47	41·7	51 ·1
	G3	R	0	4	49	4	40	0	4	51·2				54 ·4
		L		5	16	4	40							50 ·4
														294′ ·1
Arc II.	G3	L	210	2	24	1	45	210	2	05·9				Mean 58° 34′ 49″·0
		R		2	25·5	1	49				58	34	41·9	
	G2	L	268	36	57	36	27	268	36	47·8				
		R		37	14	36	33				69	33	06·4	Angle G2-B6.
	B6	L	338	9	59	9	38	338	9	54·2				
		R		10	28	9	32				164	4	11·9	69° 33′ 12″·3
	B8	L	142	14	24	13	41·5	142	14	06·1				8 ·5
		R		14	25	13	54				67	47	56·0	7 ·5
	G3	L	210	2	13	1	33	210	2	02·1				6 ·4
		R		2	28	1	54·5							17 ·9
														9 ·6
														62′ ·2
Arc III.	G3	R	270	3	24	2	54·5	270	3	02·9				
		L		3	17·5	2	35·5				58	34	49·2	Mean 69° 33′ 10″·6
	G2	R	328	38	14	37	54·5	328	37	52·1				
		L		38	5	37	15				69	33	12·3	
	B6	R	38	11	35	10	59	38	11	04·4				
		L		11	10·5	10	33				164	04	07·5	
	B8	R	202	15	44	14	59	202	15	11·9				
		L		15	11	14	53·5				67	47	52·1	
	G3	R	270	3	31	3	1	270	3	04·0				
		L		3	12	2	32							

2. The differences between successive "means" were written in the column "angles."

3. The six different values for each angle were collected in the last column of the form, and the means taken.

Angles were not adjusted for closure of the centre at this stage, nor in general were corrections for errors of runs of the micrometers applied.

Two methods of checking the computation were employed:

1. For several years, the computation described above was made by one computer, and repeated by another.

2. Later, another system was adopted. With the aid of a comptometer, the minutes and seconds of all the settings made on each station were added up, and so the mean setting on each station was computed. Then, the differences between the mean settings should be equal to the mean angles as computed before.

Skeleton Maps.—Great use of skeleton maps of the triangulation and traverse has been made in all stages of the work. The best existing maps of the district to be surveyed were used, and the triangulation marked on it as points were selected. By various conventions, it was possible to exhibit points that had been definitely selected in reconnaissance, and points where the angular observations had been definitely accepted. Thus, at a glance, the state of the work could be gauged at any time, and a better control could be exercised over the general execution of the work. As observations arrived, a more accurate diagram of the triangulation was drawn by protractor and used in a similar manner, to show the progress of the computation.

Occasionally, these maps were used as graphical computing devices to give rough checks on the arithmetical computations.

Thus, by showing eccentric stations (which were frequent in Lower Egypt), in their true azimuth, but at an exaggerated distance from their primary stations, it is possible to compute approximate values of the reductions to be applied to the observed angles to obtain the angles at the primary station. This use of the maps * depends on the fact that the ratio of the angles so measured to the angles derived from

* Due to Mr. T. L. BENNETT, inspector in the Computation Office.

arithmetical computation is approximately the same as the ratio between the distorted and true distances. The diagram in Plate XIV exhibits the method.

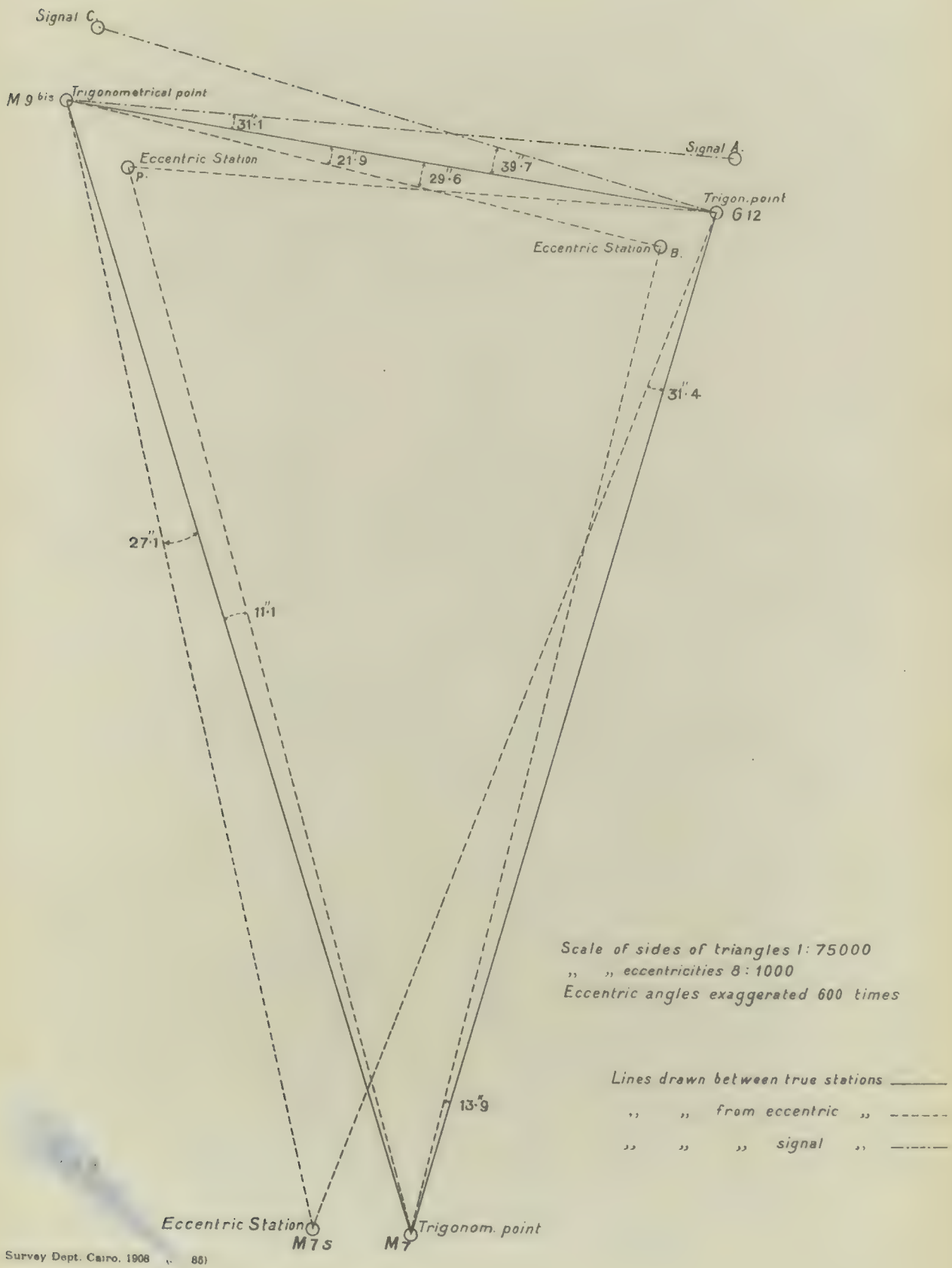
Another way in which skeleton diagrams, not necessarily drawn to scale, were employed, was to detect the site of gross errors. For the triangulation, the angular error of closure was entered with its sign in each triangle, and a scrutiny of the diagram frequently enabled the Computation Office to indicate to the field-party which point should be occupied first to clear up an inadmissible error. This method becomes increasingly useful as the scale of survey descends. Thus it was used only occasionally for the second order triangulation; much more frequently in third order; and continually in the traverse work. Example of this use in the third order triangulation and in the traverse work are exhibited in Plates XV (fig. 1) and XVI.

In the first case the errors are so gross that it is clear that point 133 must have been moved between the observations to it and those from it. The inspector in charge of the triangulation was informed, and the point was replaced as nearly as possible in its old position but treated as an entirely new point, all old observations to it being cancelled.

For the traverse computation, the diagrams used were of the roughest description since the labour of drawing a fairly accurate sketch is considerable. But in cases where large scale maps already exist, such sketches can easily be made, and are much preferable to very rough diagrams. It was found advisable, however, in keeping tally of the progress of the field-work and computation, to use the best maps available on a scale of 1 : 100,000. On these, rough boundaries were drawn as the field-work was received, and by a convention as to colour or shading, the state of the work in each markaz was shown clearly and comprehensively. This was particularly useful for indicating in what localities field-work was behindhand, and when it was being pressed on unnecessarily and at the expense of other districts.

Maps of the triangulation drawn to scale were used for finding the spherical excess. If E is the spherical excess in seconds, $E = 206200\ A/a^2$, where A is the area of the triangle in square kilometres, and a is the mean radius of the earth at the triangle. With Clarke's figure of the earth this formula becomes: $E = A/196{\cdot}5$. As the spherical excess never exceeded 5″ for any triangle, a sufficient approximation was obtained by dividing the area in square kilometres by 200, for the error so introduced never exceeded 0″·1.

LYONS CAD. SUR. EG.



Survey Dept. Cairo. 1908 (. 88)

Using this graphic method, one could always find the area of the triangle, and hence the spherical excess, correct to one per cent, or with the approximate rule to three per cent, a precision more than sufficient for the largest triangles. The residual error was thus thrown into the error of closure of the triangle.

Adjustment of the Secondary Angles.—In the Delta, the triangles formed interlacing central polygons, and along the valley, quadrilaterals, each independent of the next, so far as the angular measurements went. The resulting complexity in the Delta indicated the reduction of large blocks of the triangulation as the best method to be followed, but the time available did not permit of the adoption of this method, and the whole was reduced by successive polygons. Angles which had already been adjusted in one polygon were treated as errorless in an adjacent one into which they might enter. In Daqahlia, difficulty arising from this source was avoided by the plan of occasionally leaving a gap over which the errors were distributed, so that accumulation was prevented and the errors were kept within reasonable limits. In 1908, after the high pressure under which the work had to be turned out had ceased, a part of Menufia and a part of Gharbia were each reduced as one figure, and the same procedure will be adopted in the remaining part of Gharbia, which will complete the secondary triangulation of the cultivated area of Egypt.

In the Nile Valley, the independent quadrilaterals presented no difficulty, and no artifice was necessary to prevent accumulation of error, since adjustments had never to be carried from one figure into the next. When the secondary triangulation of the Delta is complete, the adjustment of the whole will be re-considered.

The figures were always adjusted by the method of least squares, treating all angles as of equal precision. As being somewhat the easier of the two, the method of angles was adopted in preference to that of directions. The method of least squares was adopted, largely because it gives a unique solution of the problem of finding a system of corrections which, applied to the angles, will make the whole figure self-consistent. Other approximate methods might have been adopted, which would have given corrections practically negligible in their effects on the accuracy of the maps, but nearly all leave too much to the judgment and experience of the computer, and in the beginning

of the work, at any rate, when the computers were being trained, and even for some years after, it was undesirable to trust too much to their judgment. The method had, of course, the additional advantage of giving the most probable system of corrections *à posteriori*.

The theory and examples of the methods adopted will be given in a special publication* on the theory of the computations in use in the department.

Adjustment of the Chains of Triangulation.— Theoretically, the whole of a triangulation should be reduced by the method of least squares as one piece, but in practice this is seldom done, and the triangulation is divided into blocks which are reduced separately and successively, the corrected angles, where they affect two blocks, being considered errorless for the second of the two. Even with this simplification, the procedure is tedious and demands time. In the geodetic triangulation of Great Britain and Ireland, a triangulation consisting of 218 points occupied an average of eight computers for two and half years, and although the network in Egypt is undoubtedly much less complex than that in Great Britain, still it would have required from three to six months for each of the eleven blocks here. The reasons for pressing the detail survey at maximum speed have already been mentioned, and need not be referred to again here, other than to say that, with the exception of part of Qena, there has been no part of the triangulation where a delay of over a month in the utilization of the reduced results of the triangulation would not have delayed the detail survey. Tedious rigid methods had, therefore, to be put aside as impracticable, and some manner of rendering the whole triangulation consistent had to be adopted, which, while not doing too great violence to the observations, would yield results of a sufficient precision, though not of the greatest probability, without delay. This condition is admirably fulfilled by the method devised by the Great Trigonometrical Survey of India† to obtain approximate positions in circumstances somewhat similar to those that obtained here.

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* Survey Department Paper No. 12. (in the press).

† "Great Trigonometrical Survey of India." (Vol. II, p. 169.)

The corrections thus obtained were in general small, in spite of the fact that the bases at the two ends of the chain were frequently measured by different kinds of base apparatus and presumably, therefore, were referred to different standards.

The annexed table exhibits the chains so corrected with the number of triangles in each and the correction applied to each angle:—

CORRECTIONS TO ANGLES FOR ADJUSTMENT FROM BASE TO BASE.

		No. of triangles
Fayum	0″·16	39
Addendan-Dakka	0″·71	87
Dakka-Khattara	0″·08	15
Khattara-Gebelein	1″·19	27
Gebelein-Ambir	0″·30	29
Ambir-Tema	1″·63	19
Tema-Roda	0″·11	16
Roda-Feshn	0″·44	24
Feshn-Seila...	0″·27	9
Seila-Moqattam	2″·10	11
Moqattam-Tel el Kebir	0″·10	6
Tel el Kebir-Ras el Khalig	0″·40	13
Waqed-Halq el Gamal	0″·50	15

For the purpose of comparison, the chain between Ambir and Tema bases was adjusted also by a second method. The greatest correction to an angle so obtained was 3″·62; and the greatest difference between the two lengths of a side obtained by the two methods was 0·59 metre on a length of 18,126 metres.

The corrections thus obtained are applied to the respective angles, and the chain of triangles becomes self-consistent, so that there is only one value for each side. When this has been done, there remain in each quadrilateral or polygon some angles which have thus been rendered inconsistent with those corrected. The quadrilateral or polygon is adjusted by the method explained below in discussing the third order triangulation. In this way, the whole block of triangulation is rendered self-consistent, and the value of a side is independent of the path by which it has been computed.

When angles so corrected afterwards appear in other chains, they are considered errorless.

Reduction of Minor Polygons.

Centre No. B6

	°	′	″	″			
1	34	01	25·8	25·8		747	8294
4	66	16	45·5	45·4		961	6665
7	62	33	47·3	47·3		948	1777
10	61	24	56·7	56·7		943	5511
13	57	08	33·7	33·7		924	2919
16	78	34	31·2	31·1		991	3085
	360	00	00·2	00·0			

No.	Angles observed.			Correc. for Δ	Correc. for side.	Log. Sines.		Corr.	Diff.	No.	Angles observed.			Correc. for Δ	Correc. for side.	Log. Sines.		Corr.	Diff.
	°	′	″	″	″						°	′	″	″	″				
2	109	09	15·0	16·5	15·6	9752	648	654	—7·3	3	36	49	16·1	17·7	18·6	7776	625	650	28·1
5	61	35	30·2	31·8	30·9	9442	770	760	11·4	6	52	07	41·1	42·8	43·7	8972	917	932	16·4
8	65	22	47·9	46·2	45·3	9586	055	046	9·7	9	52	03	28·1	26·5	27·4	8968	715	730	16·4
11	49	03	09·4	08·6	07·7	8781	247	231	18·3	12	69	31	55·5	54·7	55·6	9716	778	785	7·9
14	58	32	47·8	48·2	47·3	9309	826	815	12·9	15	64	18	37·8	38·1	39·0	9548	005	014	10·1
17	36	02	36·2	37·4	36·5	7696	745	719	28·9	18	65	22	50·2	51·5	52·4	9586	106	114	9·6
						4,569	291	225	81·2							4569	146	225	88·5
			145				146		—7·3										73·9
				=0′·9															
			162·4				145		73·9										162·4

Adjustment of the Third Order Triangulation.—The problem here is practically the same as in the second order triangulation ; the equations of condition are the same in number and kind ; but a satisfactory solution will be obtained if any set of corrections is found whose influence on the plotted positions of points is negligible, and it is not here necessary to find the most probable set of corrections. The method adopted was the following. To fix ideas, consider a polygon of n sides and let the central error of closure be e_0, the triangular errors of closure e_1 e_2 . . . . . and the error of closure of the side equation e_s.

Then, if X, Y, Z, are the angles of any triangle, X being at the centre, and Y on the left as viewed from the centre, the error x in X was taken to be e_0/n, that of Y to be $\frac{e_1}{2} - \frac{e_0}{2n} + \frac{e'_s}{[s]}$, and that of Z, $\frac{e_1}{2} - \frac{e_0}{2n} + \frac{e'_s}{[s]}$, where s_y is the tabular difference in log. sin. Y for 1″ difference of Y and $[s]$ denotes the sum of all the s's, and e'_s will presently be defined.

It is evident that $x_1 + x_2 + \cdots + x_n = n\, e_0/n = e_0$

$$x + y + z = \frac{e_0}{n} + \left(\frac{e}{2} - \frac{e_0}{2n} + \frac{e_s}{[s]}\right) + \frac{e}{2} - \frac{e_0}{2n} - \frac{e_s}{[s]} = e$$

and that $[s_y\, y - s_z\, z] = \left[\frac{e\, s_y}{2}\right] - \frac{e_0}{2n}[s_y] + \frac{[s_y]}{[s]} e'_s$

$$- \left[\frac{e\, s_z}{2}\right] + \frac{e_0}{2n}[s_z] + \frac{[s_z]}{[s]} e_s$$

$$= \left[\frac{e\,(s_y - s_z)}{2}\right] - \frac{e_0}{2n}[s_y - s_z] + e'_s$$

If now $e'_s = e_s - \left[\frac{e\,(s_y - s_z)}{2}\right] + \frac{e_0}{2n}[s_y - s_z]$, $[s_y\, y - s_z\, z] = e_s$, and it is clear that e'_s is the error of closure of the side equation that results if we first correct the base angles for triangular and central errors of closure and deduce the error of closure of the side equation from the partially corrected angles.

Hence, we have the following rule: First correct the angles at the centre by distributing the central error of closure. This adjustment

will give new values for the triangular errors of closure. Correct the base angles by applying half of the new error of closure in each triangle, with reversed sign. This adjustment would disturb the equation giving the error of closure of the side. Compute this new side error of closure; divide it by the sum of the tabular differences in the logarithmic sines for a change of 1″ in the base angles; and apply the quotient as a correction, additive to one base angle and subtractive to the other. The sign is most easily determined for each case by inspection.

As an example and for the sake of comparison, a hexagon already reduced by the rigid method was re-computed by this rule with the following resulting corrections :

Angles... ...	1	2	3	4	5	6	7	8	9
Seconds by rigid method	0·0	+1·1	+2·3	+0·7	+0·7	+2·4	−1·4	−1·3	+0·3
Seconds by approximate method. ...	0·0	+0·6	+2·5	−0·1	+0·7	+2·6	0·0	−2·6	−0·7
Difference ..	0·0	+0·5	−0·2	+0·8	0	−0·2	−1·4	+1·3	+1·0

Angles... ...	10	11	12	13	14	15	16	17	18
Seconds by rigid method	−0·5	−1·0	+0·6	+0·1	−0·1	+1·3	+0·9	−0·2	+2·1
Seconds by approximate method. ...	0·0	−1·7	+0·1	0·0	−0·5	+1·2	−0·1	+0·3	+2·2
Difference ...	−0·5	+0·7	+0·5	+0·1	+0·4	+0·1	+1·0	−0·5	−0·1

Angles adjusted in one figure were considered as errorless for the next. The modification thus introduced into the rule is easily made.

The Figure of the Earth Used.

In 1900 it was considered that the spheroid investigated by Clarke* gave the best representation of the mean form of the earth, and this, or his earlier figure, calculated in 1866, was used in most English-speaking and some other countries for geodetic computations. In a considerable number of countries, notably Germany, Austria, Italy, Russia and Denmark, the elements computed by Bessel in 1841 were still used, and in the computations of the geodetic survey of South Africa both Clarke's and Bessel's figures were made use of. As the result of this comparison, Sir D. Gill † reported, that the meridians were better represented by Clarke's figure and the parallels by that of Bessel.

The experience of the most modern surveys seemed, in 1900, to point to Clarke's as the better of the two spheroids, and accordingly it was decided to project the triangulation on it. Tables based on it had already been computed for the use of the American Coast and Geodetic Survey: they depended on the value for the metre adopted in the United States, viz. 39·37 inches in place of 39·370113 inches, that found by the Bureau International des Poids et Mesures, ‡ but the difference is insignificant and may be neglected. The tables were therefore adopted without alteration, and were used for the first time in 1900 to compute the geodetic positions of the trigonometric points in the Fayum. In the meantime, a form of projection had been decided on (see page 273), and the formulae for the co-ordinates prepared. No tables based on Clarke's figure, however, were available for this projection, and it became necessary to utilize the results of the Fayum triangulation before the staff had time to compute such tables. It was, therefore, reluctantly decided to plot the maps of the Fayum province on the polyhedral system, and to defer using the projection till the triangulation of Daqahlia and Qaliubia, then in progress, was required. But here again the staff never had sufficient time to compute the tables, and the case of the Fayum appeared about to be repeated,

* "Philosophical Magazine," August, 1878.

† "Origin and Progress of Geodetic Survey in South Africa," by Sir David Gill, K.C.B., F.R.S. Report of the British Association, 1905, p. 228.

‡ "La Convention du Mètre." Paris, 1902, p. 101.

unless Bessel's figure, for which certain tables existed, was made use of, in place of the other. It was decided to do so, and so the latter was employed for the computation of the geodetic positions, and the former for the map projection.

In 1903, Dr. R. Helmert published a report in the transactions of the International Geodetic Association (1903, Vol. II, p. 441), in which he confirmed the value for the equatorial semi-diameter found by Clarke, and the value for the compression found by Bessel, and this conclusion has since been confirmed by the work of the American geodesists.*

Helmert, in a more recent discussion, has slightly modified his 1903 conclusion, but without altering the general result, that Clarke's equatorial semi-diameter and Bessel's compression give the best representation of the available measurements.

	Equatorial semi-diameter.	Reciprocal of the compression.
	m.	
Bessel 1841	6,377,397	299·2
Clarke 1866	6,378,206	295·0
„ 1880	6,378,249	293·5
Helmert 1903	6,378,035	299·2
American Survey	6,378,283	297·8

It will be seen from a comparison of these figures that Bessel's semi-diameter is about one part in 10,000 too small if we accept Helmert's 1903 result. (See also p. 276).

Astronomical Positions.

Strictly speaking, only three astronomical latitudes and longitudes, those of Cairo, Luxor, and Addendan, were employed for the Cadastre, although several others were determined. Thus a longitude and several latitudes were observed in the Fayum, but since the system of projection adopted had not come into full operation, the only use of the latitude was as argument in entering the tables used for the computation of the consecutive azimuths of the triangulation lines. In the same way, latitudes were observed at Roda, Tema, Dakka and

* "Comptes rendus de l'Association Géodétique Internationale." Berlin, 1908, p. 228.

other places, but these served only as very rough controls of the triangulation, and will be better discussed with the topographical survey of Egypt.* The positions actually made use of for the operations of the triangulation on which the maps of the Cadastre were based were the following :—

Cairo	Abbassia, Latitude and Azimuth. Moqattam Hill, Longitude.
Luxor	(Temple Obelisk), Latitude, Longitude. (Point 11 of the triangulation), Azimuth of point 811.
Addendan ...	(Base-line), Latitude, Longitude and Azimuth.

Latitude at Abbassia.—The fundamental latitude adopted is that of the transit instrument at the old Khedivial Observatory at Abbassia, now removed to Helwan. The method employed and results obtained have been fully explained by Mr. E. B. H. Wade †, by whom almost all of the astronomical work was done.

The transit instrument was used as a zenith telescope and the latitude found by Talcott's method. The resulting latitude was :

$$30^\circ\ 04'\ 35''{\cdot}83 \pm 0''{\cdot}15$$

Latitude at Luxor.—When at Luxor for the Transit of Venus in 1874 Professor Auwers observed a latitude from which he deduced that of the obelisk of Luxor Temple as 25° 41′ 58″·84. Since, however, this was not the most convenient site for a measurement of azimuth, a latitude was observed by Mr. E. B. H. Wade at station 11 of the second order triangulation. Two methods were employed : (*a*) by observation of meridian zenith distance employing circle readings; (*b*) by observation of the times of transit over a fixed almucantaric circle. This second method has been described by Mr. Wade ‡ and will be described in somewhat greater detail in the report on Topographical Surveying. In each method the probable error of a single observation was of the same order, about 0″·6, and so the different groups have

* "Recent Topographical Surveying in Egypt," by Capt. H. G. Lyons. (in the press).

† "Report on the Meteorological Observations during 1900," Survey Department, Cairo, 1902, p. 52.

‡ "Monthly Notices of the Royal Astronomical Society." 1901, vol. 64, p. 107-112.

been given weights equal to the number of observations in each. The results obtained for the latitude were :—

By equal altitudes,	1903 February	26,	25° 44′ 12″ ·0	weight	5
.. .. ..	.. ..	27,	10 ·4	..	5
.. .. ..	.. ..	28,	11 ·0	..	8
By meridian zenith distances,	,,	24-28,	10 ·8	..	14

The weighted mean thus gives for station 11 the latitude 25° 44′10″·96 ± 0″·15.

Latitude at Addendan.—Since Addendan was the furthest south point of the triangulation at which astronomical observations were likely to be taken, it seemed desirable to make these as precise as possible, without unduly delaying the work. Accordingly, Mr. Wade was instructed to measure the latitude at several neighbouring points, and then reduce the results by triangulation to one of them, namely, the south-west end of the base-line. The points were named Nos. 1, 2, 3 and 4, the last being the south-west end of the base-line. From the triangulation the following reductions to observed latitudes, to deduce the latitude of point No. 4, were found :—

Station 1	+ 48″·9
,, 2	+ 33 ·4
,, 3	— 2 ·1
,, 4	0 ·0

Observations were made by two different methods :—

(*a*) By measurement of meridional zenith distances on the graduated circle of the theodolite ;

(*b*) By the method of equal altitudes, without having recourse to circle readings.

The former method was subject to errors of graduation of the circle, but as the zenith distances of pairs of north and south stars were nearly equal, the residual effect of these errors was small. Only stars very near to the zenith were employed in this method. The second method is independent of circle errors.

Collecting the different results, we obtain the following :—

LATITUDE AT ADDENDAN.

Zenith distances.

Station.	Date.	Latitude.	Reduction to No. 4.	Deduced latitude of No. 4.
1 ...	1903 Nov. 13 ...	22° 13′ 56″·5	+ 48″·9	22° 14′ 45″·4
1 ...	„ „ 14 ...	22 13 56 ·9	+ 48 ·9	45 ·8
2 ...	„ „ 17 ...	22 14 13 ·4	+ 33 ·4	46 ·8
3 ...	„ „ 18 ...	22 14 49 ·4	− 2 ·1	47 ·3
4 ...	„ „ 21 ...	22 14 46 ·0	0 ·0	46 ·0

Mean of the results from four stations = 22° 14′ 46″·3.

Equal altitudes.

Station.	Date.	Latitude.	Reduction to No. 4.	Deduced latitude of No. 4
1 ...	1903 Nov. 14 ...	22° 13′ 57″·5	+ 48″·9	22° 14′ 46″·4
2 ...	„ „ 15 ...	22 14 11 ·7	+ 33 ·4	45 ·1
3 ...	„ „ 18 ...	22 14 50 ·9	− 2 ·1	48 ·7
4 ...	„ „ 21 ...	22 14 48 ·95	0 ·0	49 ·0
— ...	„ „ 24 ...	22 14 45 ·9	0 ·0	45 ·9

Mean of the results from four stations = 22° 14′ 47″·0.

In combining these results double weight was given to the latitude by zenith distances, and as the general mean it was concluded that the latitude of Addendan, south-west point of the base, was 22° 14′ 46″·5.

The probable error deduced from the differences between the determinations is ± 0″·23.

Longitude near Cairo.—For the purposes of the cadastral maps, the longitude is not required, but since the ultimate reduction of the large scale maps to the scales of 1 : 10,000 and 1 : 50,000, etc., for the topographical maps, was always kept in mind, it became necessary to incorporate in the triangulation at least one point whose longitude was known with sufficient accuracy for the topographical maps. Such

a point was available in the position occupied by the British party who visited Egypt to observe the transit of Venus in 1874. On that occasion, the difference of longitude between Greenwich and the transit instrument at the station on the Moqattam Hill was determined directly by exchange of telegraphic signals, on November 14, 15, 21 and 22, 1874. A full account of the operations * was published by Capt. Orde Browne under the direction of Sir George Airy, so that only the result need be given here.

Captain Orde Browne's general conclusion is that the concluded longitude of Moqattam is obtained as follows:

Apparent longitude east of Greenwich	2^h	5^m	$6^s \cdot 58$
Correction for personal equations in giving and receiving signals.		-	$0 \cdot 09$
Correction for personal equations in observing transits		—	$0 \cdot 25$
Concluded longitude of Moqattam east of Greenwich	2^h	5^m	$6^s \cdot 24$

There is, certainly, a probable error of $\pm$ $0^s \cdot 062$ due to those of the personal equations in observing transits and in receiving signals over the submarine cables, and it is not unlikely that the whole error amounts to thrice this figure. Sir David Gill, in the Annals of the Cape Observatory, arrives at the mean error $\pm$ $0^s \cdot 098$ and thinks that the mean error of the combined equations is certainly not underestimated at $\pm$ $0^s \cdot 35$, agreeing in both cases with the figures given above.

Longitude, Luxor.—For administrative reasons it was decided to survey Upper Egypt from Qena province northwards and southwards, and triangulation operations were commenced there in 1902. Since there was no hope that a continuous triangulation from Qena to Cairo could be completed before the maps were wanted by the field-parties, the choice of a subsidiary astronomical origin became necessary. Fortunately, a suitable point was available in the obelisk at Luxor, the position of which was determined by Professor A. Auwers in 1874, when he visited Egypt to observe the transit of Venus. His longitude was determined by exchange of telegraphic signals with Moqattam on Dec. 1, 4, 10 and 15, 1874; and a full description of the method has been published by him.†

* "Observations of the Transit of Venus, 1874, December 8," edited by SIR GEORGE BIDDELL AIRY, K.C.B. (London, H.M. Stationery Office, 1881).

† "Bericht über die Beobachtung des Venus Durchgangs," von A. AUWERS, Berlin, 18[illegible]8.

His general conclusion was that the longitude of the obelisk of Luxor Temple was $2^h\ 10^m\ 33^s{\cdot}87$ east of Greenwich, which was adopted as the value for the survey of this part of the country.

Longitude, Addendan. — In 1903, it became necessary to execute another detached piece of triangulation in Aswan, and accordingly another fundamental astronomical point had to be found. There was not time to join this part of the triangulation to the point in Wadi Halfa whose position had been determined by Col. the Hon. M. G. Talbot, R.E., in 1893, and again in 1897, by direct telegraphic comparison with Abbassia Observatory, and the value supplied by Mr. Wade as that of the south-west point of Addendan base was adopted. This longitude depended on the transport of a chronometer from Abbassia Observatory to Addendan and back. The method is not very reliable and the longitude, which was purely provisional, was only utilized from force of circumstances. The result gave : —

	h.	m.	s.	
Chronometer slow	4	01	42·7	on Addendan L.S.T.
„ „	4	01	33·6	on Abbassia „
Longitude of Addendan :	—	—	9·1	east of Abbassia
„ „ Abbassia :	2	01	8·6	„ „ Greenwich
„ „ Addendan :	2	05	17·7	„ „ „

As soon as the triangulation was joined to Wadi Halfa, it was found that this value was considerably in error but in the meantime it had served its purpose, and when the whole triangulation was completed, the necessary correction of $+ 46^s{\cdot}0$ was made.

Azimuth at Abbassia.—The azimuth of the triangulation point I on the Moqattam Hill as seen at point O situated on the Observatory, was found in three different ways :

(1) By direct observation of the angle between Polaris (observed in daylight) and the point I.

(2) By finding the angle between Polaris, observed near the meridian, and a meridian signal, and that between the triangulation point and the signal. The determination of the differences of azimuth of Polaris

and the signal was made with a micrometer only, and the telescope was reversed after each pair of observations.

(3) By observing transits over the meridian mark and deducing the azimuth error of the instrument in the usual manner. It should be mentioned that the azimuths were here observed not at point O, but at an eccentric station 609·3 centimetres south and 106·0 centimetres east of point O, and angles were afterwards reduced to the trigonometrical point.

To obtain the general mean each method was weighted according to the number of "observations," the unit of observation being the mean of four micrometer bisections, or of three threads in a transit. Further, since the instrument was mounted in a much more stable position in the third method than in the other two, an additional 50 per cent of weight has been allowed here. We have the following results:

Method.	Azimuth.	Probable Error.	Weight.
1	189° 59′ 54″·98	± 2″·4	4
2	66 ·72	2 ·4	9
3	64 ·86	1 ·0	13·5

Weighted mean ... ... 190° 00′ 04″·00 ± 1″·0

If weights inversely proportional to the squares of the probable errors are taken, the mean is found to be 190° 00′ 03″·83.

Azimuth at Luxor. — The azimuth adopted at Luxor was that of station 811 of the third order triangulation on the horizon of station 11 of the second order. The results were as follows:—

1903 February	27	from α Cephei	30° 33′	22″
,, ,,	,,	β ,,		25
,, ,,	,,	ι Centauri		41
,, ,,	,,	β ,,		17
,, ,,	28	α Virginis		20
,, ,,	,,	α Cephei		22
,, ,,	,,	β ,,		28
		Mean...	30° 33′	25″·0 ± 2″·0

This azimuth was adopted and was used for the whole triangulation from Dakka north to Cairo. Subsequent observations at Luxor and other points of the triangulation seem to indicate that the azimuth of side 11–13 deduced from this was in error by 22″, but this point does not concern the accuracy of the Cadastre and will be discussed in the report on the Topographical Survey.

Azimuth at Addendan.—This was observed directly by measuring the horizontal angle between Polaris and a signal placed near the north-east end of the base-line. The results were spread over two evenings and in all ten values of the azimuth were obtained. The usual reversals of the instrument were made, and as the star was observed both east and west of the meridian, and close to it, any error in its declination will disappear.

The results on the two evenings were :—

Azimuth of the north-east end of the base at the south-west end :

	54° 06′ 42″·65	±	1″·05
	54° 06′ 43 ·3	±	0 ·90
Mean ...	54° 06′ 43″·0	+	0″·7

Computation of Geographical Positions.

The method used in carrying computation of latitude, longitude and azimuth through the triangulation is shown in the example below.

A strong check is furnished by the agreement of the positions for a point found by proceeding by two or more different routes. It has been found undesirable to compute first round a circuit, distributing the residual error of computation and them to compute inwards to the interior points. The present practice is to proceed uniformly across the country, carrying the computation along every observed line. In this way no discrepancies exceeding 0″·004 in latitude or longitude or 0″·1 in azimuth are found, provided that the figure adjustment is correct.

Computation of Latitudes, Longitudes and Azimuths of B11 Station.

B11 computed from B10

$-\delta\varphi_0 = l\cos\alpha_0 B + l^2\sin^2\alpha_0 C + l^2\cos^2\alpha_0 B^2 D.$
$-\delta\lambda_0 = l\sin\alpha_0 A'\cos\varphi.$
$-\delta\alpha_0 = \delta\lambda\sin\frac{1}{2}(\varphi + \varphi_0).$

α_0	B10 to B11		194°	08′ 16″·3
$\delta\alpha_0$	... ...	+		1 35 ·9
180°	... ...	+	180	
α	B11 to B10		14	09 52 ·2

φ_0		30°	54′	44″·538	λ_0	30°	17′ 22″·778
$\delta\varphi_0$	+		10	36 ·292	$\delta\lambda_0$	+	3 06 ·230
φ		31	05	20 ·830	λ		30 20 29 ·008

l

log l		4·3055		393
log cos α_0		$\bar{1}$·9866		423
B_0		$\bar{2}$·5115		066
log 1st. term		2·8036		882
1st term	−		636″·338	
2nd. and 3rd. terms	+		0 ·046	
$-\delta\varphi_0$	−	0°	10′	36″·292
$+\delta\varphi_0/2$	+		5	18 ·146
φ_0		30	54	44 ·538
$(\varphi + \varphi_0)/2$		31	00	02 ·684
log C_0		=	$\bar{9}$ · 18264	
2 log l		=	8 · 61108	
2 log sin α_0		=	$\bar{2}$ · 77567	
			$\bar{2}$ · 56939	
Nat. number		=	0 · 037	

A′		$\bar{2}$·5093	334
log l		4·3055	393
log sin α_0		$\bar{1}$·3878	350
sum		2·2027	077
− log cos φ		$\bar{7}$·9326	590
log $(-\delta\lambda_0)$ = diff. ...		2·2700	487
log sin $\frac{1}{2}(\varphi + \varphi_0)$ ...		$\bar{1}$·7118	487
log $-\delta\alpha_0$		1·9818	974
$-\delta\alpha_0$	−	95″·9	
log D_0	=	$\bar{8}$ · 3377	
2 log 1st. term	=	5 · 6074	
		3 · 9451	
Nat. number	= +	0 · 009	

Map Projection.

Previous to 1900, no attempt to draw the large scale maps of Egypt on any connected system of projection had been made.* The co-ordinates for each village were computed separately, and the origin chosen in such a way that the village could be arranged more or less symmetrically in the middle of its own sheets. As the villages dealt with were mostly of no great area, their maps could be drawn *in plano*, and no other system of projection for each was necessary.

It may not be out of place to refer here to the very great advantage accruing from the adoption of a system of projection when there is a probability that the large scale maps will be reduced to smaller scales for topographical purposes. Owing to shrinkage, which in Egypt is always considerable, it is seldom that the boundary of one completed village will be found to agree with that of the neighbouring one, and much difficulty has been experienced in combining maps of villages in all the provinces where the polyhedral method was adopted for the cadastral sheets. It is doubtlessly possible, in fitting together piecemeal results of this sort, to lay off the exact position of certain points and then place the different villages so that the points corresponding to those thus plotted would come in their correct places, but the labour involved in this method of working would be almost prohibitive and the interpolation of the detail demands a higher degree of intelligence and skill on the part of the draughtsman than is usually obtainable in Egypt.

In any case, whatever advantage the polyhedral method may possess when the village is the unit, as in the Cadastral Survey, is immediately lost when the production of topographical maps is in question, for it is manifestly impossible to publish such maps with irregular boundary lines; some system of drawing straight sheet lines—in other words, some system of projection—becomes necessary. This need, in the case of the topographical maps, was recognized by making these the unit in the system of numbering adopted (see p. 280). When such a system of drawing graticules has been adopted, the difficulties of fitting shrunken sheets into their proper rectangles on the reduced

* Projections had, of course, been used for atlas and small scale maps; thus Mahmud Pasha el Falaki used the Sanson-Flamsteed projection for his map of the Delta published in 1872.

scale become much simplified and may generally be overcome by a slight adjustment of the pantograph.

While it is always necessary for topographical maps, a system of projection becomes mainly a matter of convenience for cadastral maps; for the chief advantages in this case are that the process of checking the fit of common village boundaries is much facilitated and the labour of printing is much reduced.

For administrative reasons, it was necessary to adopt the village as the unit of survey in the cadastral work. Accordingly, where parts of several villages were to be represented on the same map sheet, this sheet had to be issued in blank for each village, and as the sheets were frequently plotted at long intervals apart, it was necessary to check the common traverse boundary (and later the true common boundary). With a projected graticule this operation is reduced to the comparison of pairs of maps and thereby gains in simplicity. Had it been possible to discard the village and adopt the map-sheet as the unit of survey, there is little doubt that the operations would have been further simplified and the labour lessened.

Owing to the issue of duplicate sheets where parts of adjoining villages fell in the same rectangle, it was found that the effective area of each sheet was about one half, or in other words, that twice the theoretical number of traverse sheets had to be issued. This in itself entailed a certain amount of additional labour, chiefly in the plotting section of the computation office, and it would have doubled the labour of printing, had it been necessary to publish the sheets exactly as surveyed; but fortunately it was possible to print the complete sheets, so that one printing only of each was necessary. The adoption of a system of projection thus demonstrably halved the cost and time of printing at the expense of a slight additional amount* of labour in the computation office, a slight delay in the issue of sheets common to two or more villages, and a doubled bill for plane-table paper.

As a concrete example, the case of the Fayum may be quoted, although, being roughly circular, it will exhibit less wastage of sheets along the boundary than would be the case in the long narrow provinces of Upper Egypt. The maps of this mudiria were drawn and printed

* Additional only when compared with the ideal method of discarding the village as unit and adopting the sheet. The labour and expense were rather less than with the polyhedral system.

on the polyhedral system, and there were in all 2,263 cadastral sheets. Had they been printed on the projection subsequently adopted, there would only have been 1,356, a saving of over 900 sheets or 40 % in the labour of printing, while at the same time the comparison of common boundaries would have been better done.

In 1899 it was recognized that there would be a marked advantage in having one system of co-ordinates, if possible, for the whole of Egypt. This entailed the choice of a system of projection, and the writer, then of the School of Engineering, was requested to consider the system mentioned by Tissot in his "Mémoire sur la Représentation des Surfaces"* p. 71, as being applicable to a country situated, like Egypt, in the lune between two meridians, not very far distant from one another.

Tissot's projection, however, contemplated the representation of the Nile Valley only, while it was recognized that the needs of the Geological Survey and the general geographical requirements of Egypt would soon necessitate a map of very much greater breadth. The writer investigated the corrective terms to be applied to those given by Tissot, in order to reduce the errors at the extreme limits of the map, which would have resulted from the use of his simple expression. Later, it was seen that this process must result in giving a representation of the earth's surface identical with that supplied by the conformal representation with one meridian correctly plotted, investigated by Gauss about the year 1821†, and actually used for the Hanoverian Survey. As the formulae had been revised with all necessary completeness by General Schreiber of that survey, it was decided to use them as published for the maps of the Egyptian Survey, with modifications to facilitate computation.

These formulae for the co-ordinates, as given by General Schreiber,‡ were modified to the following forms:

$$x = s_\varphi - s_0 + \frac{\lambda^2}{4}\,\frac{a}{W}\sin 2\varphi + \frac{\lambda^4}{4}\,\frac{a}{W}\,A\sin 2\varphi$$

$$y = \lambda\,\frac{a}{W}\cos\varphi + \lambda^3\,\frac{a}{W}\cos\varphi\,.\,B$$

* Paris, Gauthier-Villars, 1881.

† The development of the formulæ are contained in a letter from Gauss to H. Schumacher, published by C. A. F. Peters, Altona, 1860.

‡ Theorie der Projectionsmethode der Hannoverschen Landesvermessung, Oscar Schreiber. (Hannover, 1866).

Here, x is the northwards co-ordinate and y the eastwards one, s_φ the arc from the equator to latitude φ, s_0 the arc to latitude 30° N.

$$1/W^2=(1+\delta)/(1+\delta\cos^2\varphi)=1/(1-e^2\sin^2\varphi)$$
$$A=(1-6\cos^2\varphi-9\,\delta\cos^4\varphi-4\,\delta^2\cos^6\varphi)/12$$
$$B=(\cos 2\varphi+\delta\cos^4\varphi)/6$$
$$A=B+\cos^2\varphi\,(1+\delta)^2/(3\,W^4).$$

Tables of W for Bessel's figure of the earth are given by Albrecht,* and auxiliary tables for A and B were constructed.

The convergence of meridian, that is the angle between north and the direction of x, is given by the formula:

$$c=\frac{y}{a}\tan\chi\sqrt{\frac{1+\delta\cos^2\chi}{1+\delta}},\ \chi \text{ being a function of } x \text{ defined by: } s_\chi-s_0=x$$

It may be objected that there is an inconsistency in adopting tables based on Clarke's spheroid for computing the astronomical positions, and then Bessel's elements for the projection. The reply is that this course of action was enforced solely by the rapidity with which the results had to be obtained and made available for use. The staff was not sufficient to compute in time the tables necessary for projecting the maps according to the elements given by Clarke.

The effect of this inconsistency is to introduce a slight error in the distances plotted on the maps. For example, consider the case of two points, a known short distance apart on the central meridian.

Then we shall have:

$$\frac{\text{distance on map}}{\text{distance on earth}}=\frac{\text{Length of 1}''\text{ of meridian according to Bessel.}}{\text{Length of 1}''\text{ of meridian according to Clarke.}}$$

This fraction is less than unity by an amount varying in Egypt from 10 parts to 7 parts in 100,000. Thus from this cause the lengths on the maps are too short; but the error is to some extent minimized by other factors. The tendency of the projection is to increase lengths as one recedes from the central axis, and in all probability the lengths assigned to the bases were too long by about one part in 8,800. Thus, the errors tend to neutralize each other, and the residual inaccuracy probably does not exceed one part in 20,000.

The characteristics of the Gauss conformal projection thus adopted are:

1. Small areas on the ground are similarly represented on the map. Thus, a square becomes a square on the map, and a circle becomes a circle.

* "Formeln und Hülfstafeln für geographische Ortsbestimmungen," Leipzig 1891. (p. 264).

2. Distances measured along the central meridian are correctly represented, that is, without distortion in length, on the map.

3. The ellipticity of the earth is satisfactorily allowed for.

It is well known * that a conformal projection is the best to use when the survey of a country is based on triangulation.

Since the projection is conformal, the meridians and parallels cross at right angles, and each map-sheet is, therefore, a trapezium with curved sides. The amount of curvature, however, is so insignificant that the curved sides may be replaced by straight lines even in the sheets 1 : 50,000 without sensible departure from the truth. The map-sheet thus becomes practically a rectangle, the extreme difference between the length of the top side and that of the bottom side never exceeding 0·18 millimetre for a cadastral map sheet.

The disadvantage of this system, for, of course, every map projection has some disadvantage, is that distances away from the central meridian are slightly distorted, the scale of the map becoming larger as the eastern or western boundary is approached. Further, there is an error in the representation of areas, but the error in scale never exceeds 1 : 2,000 in the valley of the Nile, and, as far south as Girga, the whole of the country lies within the region where the distortion is less than 1 : 10,000. As this is beyond the degree of precision attainable in ordinary theodolite traverse, it follows that the error in area is negligible, compared with the errors introduced by the previous field-work. Thus, for cadastral purposes, the map is practically an equivalent, or equal-area one, and the distortions only begin to be sensible in the desert, where it is extremely doubtful whether accurate measurements of area will ever be required.

When, in the future, revision of the maps has to be undertaken, as registration becomes compulsory, areas will doubtlessly be found by mensuration in the field, and all difficulties hitherto experienced as the result of the system necessitated by the time-limit—that of measuring areas on the maps—will disappear.

Choice of Origin — Since one meridian is reproduced with fidelity, and since the scale changes as we go further and further from that meridian, it becomes important to select the centre-line of the map

* Jordan. "Handbuch der Vermessungskunde." Vol. III, p. 329 (Stuttgart, 1907).

to the best advantage. This was done in the manner recommended by Tissot.* A diagram was drawn on tracing paper, giving roughly the lines of equal distortion in length, and this diagram was superposed on a map of the Nile Valley of suitable scale, and moved about parallel to itself until the whole of the Valley and the Delta were included in a strip lying as symmetrically as possible about the central line. Somewhat greater weight was attached to the cultivated land of Lower Egypt than to that of Upper Egypt, and it was considered that there would be some advantage in making the central line coincide with a meridian an exact number of degrees east of Greenwich; therefore, after due consideration, the meridian of 31 degrees east of Greenwich was fixed on as the central axis of the map. Theoretically, any point on this may serve as origin, but there was a slight advantage in selecting the point of latitude 30°.

If it is considered that the origin of co-ordinates is a fixed point to which all the other points on the map are referred, then the point whose latitude is 30° N. and longitude 31° E. of Greenwich must be regarded as in the nature of a secondary origin, and the primary origin must be considered to be the Transit of Venus Station on the Moqattam Hill (see p. 267). The astronomical position of this point is:

$\varphi = 30° \; 01' \; 43''{\cdot}52$ N. $\qquad \lambda = 31° \; 16' \; 33''{\cdot}60$ E. of Greenwich,

and its co-ordinates on the projection adopted are:

$x = 3{,}214{\cdot}46$ metres $\qquad y = 26{,}619{\cdot}47$ metres.

These numbers may be considered as fixing the position of the origin with respect to the Transit of Venus Station, after which the point selected ($\varphi = 30°$ N., $\lambda = 31°$ E.) may be used as point of reference for the whole country.

The method adopted in projecting the maps was the following. Co-ordinates were computed for every degree of longitude and of latitude and tabulated, and a table of differences was then formed which enabled the computer to interpolate the co-ordinates of any intermediate point, and in this way the co-ordinates of all the sheet corners of the cadastral maps were found. The co-ordinates of the triangulation points were found by a separate computation (see p. 279).

It was decided that the sheet-lines should be parallels and meridians at equal angular distances, which were most conveniently fixed as $2''{\cdot}1$ in latitude and $3''$ in longitude for the cadastral sheets on the

* Op. cit., p. 51.

scale 1 : 2,500. This gave sheets varying in size from 443 millimetres in latitude by 510 millimetres of longitude to 443 millimetres by 476 millimetres, the latter lengths being the dimensions of the sheets in the extreme north on the Mediterranean, and the former being those in the extreme south near Wadi Halfa. These sheet-dimensions give a map of a size easily handled in plotting, in plane-table work, in drawing, and in printing, and it is also a convenient size for the general public. This system has the following additional advantages: that maps on the smaller scales remain practically of the same size as the cadastral maps in the same part of the country, and that, for example, sixteen cadastral maps may be fitted together and photographed down to exactly one-quarter of the size to make the topographical maps on the scale of 1 : 10,000, and from 25 of the latter the maps on the scale of 1 : 50,000 may similarly be reduced.

COMPUTATION OF SECOND ORDER CO-ORDINATES.

Mudiria Sharqia, Station 12.

$$x = S\varphi - s_0 + \frac{\lambda^2}{4}\frac{a}{W}\sin 2\varphi + \frac{\lambda^4}{4}\frac{a}{W}\sin 2\varphi\, A$$

$$y = \lambda\frac{a}{W}\cos\varphi + \lambda^3\frac{a}{W}\cos\varphi\, B$$

Latitude	30°	49′	54″·129	Longitude	31°	35′	28″·945
				Longitude	31	00	00
log Constant ...			6·463 7261	L = +		35	28·945
log L′			1·550 0130	= +		35·4824	
sum = log λ = ...			8·013 7391				

2 log λ...			6·027 4782	log λ			8·013 7391
log $\frac{a}{W}$			6·805 0245	log $\frac{a}{W}$			6·805 0245
log sin 2 φ			9·944 5687	log cos φ			9·933 8293
constant			9·397 9400				
sum = log b = ...			2·175 0114	sum = log d = ...			4·752 5929
2 log λ...			6·027 4782	2 log λ...			6·027 4782
log A			9·477 7998	log B			9·078 1729
sum = log c = ...			7·680 2894	sum = log e = ...			9·858 2440
$s_2 - s_0$			92192·67	d			56570·87
b			149·63	e			0·72
c			0·00				
x			92342·30	y			56571·59

Date 6-8-1906. *Computed by* F. C. & A. B.

The system of numbering adopted is well known and does not require lengthy description. The whole country was divided into four quadrants by the parallel of 30° and the meridian of 31° east of Greenwich. The sheets on the scale of 1 : 10,000 were taken as the basis and the position of a sheet was denoted by two numbers, the first of which gave its row north or south of the axis while the second gave its column to the east or west. Each sheet on the scale of 1 : 10,000 was sub-divided into sixteen cadastral map-sheets with consecutive numbering from one to sixteen.

Computation of Subsidiary Triangulation.

Junction of the Second and Third Order Triangulations.—The method of passing from second to third order triangulation is not generally explained in English text-books, so that the following brief explanation of the procedure adopted in this Survey may interest the surveyor.

At the time of occupation of each second order point as a station of the third order, one second order line was always included in the round of directions observed, so that the relative bearing of every second or third order line from the station was known. Starting then from a second order point, the shortest path by the sides of the tertiary triangulation to a neighbouring secondary station was selected. This with the secondary line formed a closed polygon, and lines were so short that it was always possible to select this polygon so that its spherical excess was entirely negligible.

Let AB be the secondary line (see Plate XV, fig. 2), and A*cdefg*B be the route selected by the tertiary triangulation.

Then one of the tertiary sides, such as A*c*, was given an arbitrary length, say 3,000 metres, and the corresponding lengths of *cd*, *de*, etc., were calculated. The angles between the successive sides of the tertiary polygon and the line AB were computed, and the broken line A*c* ..... *g*B projected on AB. If the length assumed for the side A*c* was correct, the projection would be equal to AB, but in general this was not so, and in that case the correct value of A*c* was found from the statement :—

The correct length of A*c* is to the assumed length as the known length of AB is to the computed projection of A*c* ..... *g*B.

When the length of one side of the tertiary triangulation had been obtained, those of the others followed, but as the third order work generally spread from a series of independent foci, the same method

LOCATION OF BAD OBSERVATIONS IN TRIANGULATION.

Fig. 1.

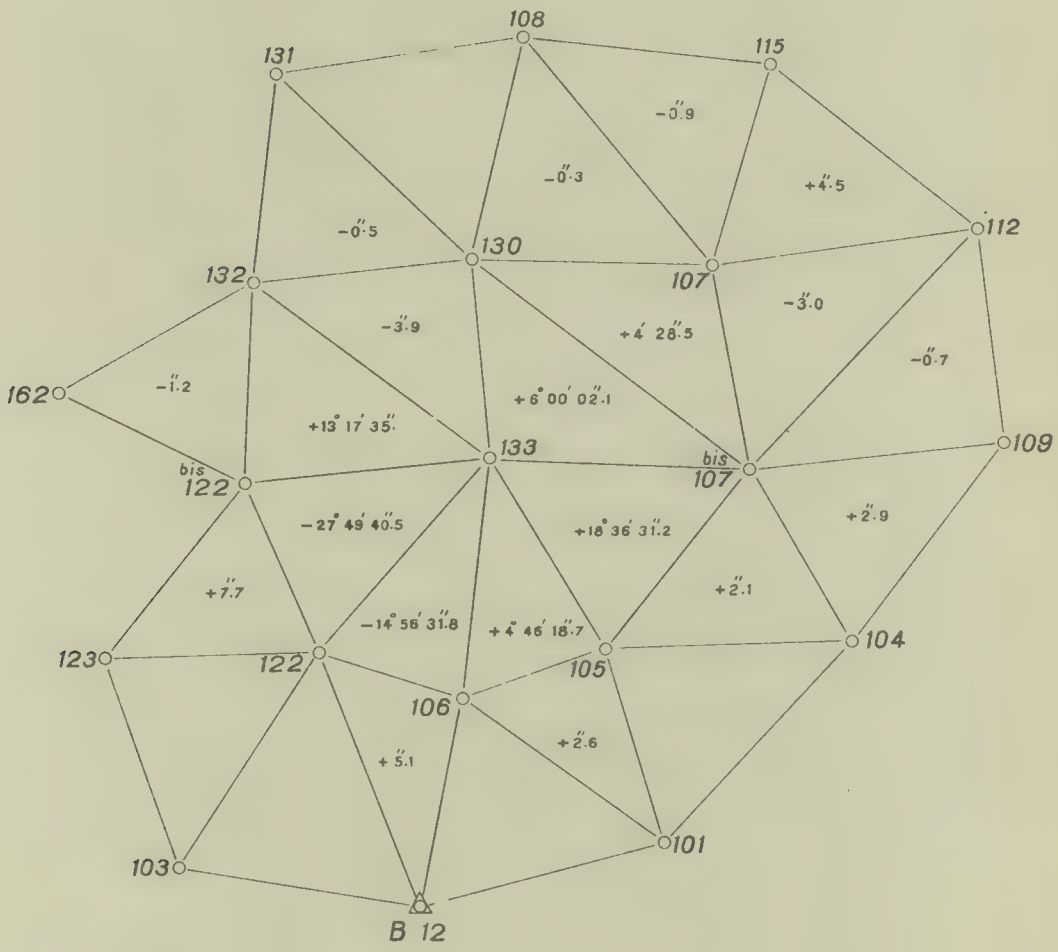
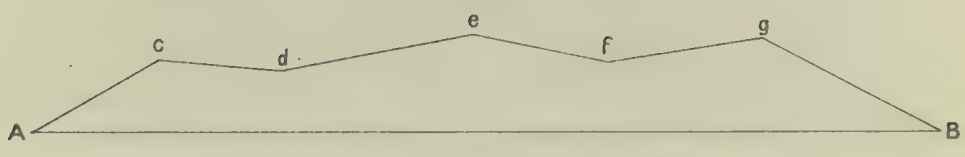


Fig. 2.



Junction of second and third order of triangulation

had to be adopted whenever the results of the tertiary work were required before the whole network was complete. It was also adopted from time to time to check the accuracy of the tertiary computations.

It is now adopted once in every second order triangle to avoid excessive distribution of error. Experience has shown that the best side of the second order triangle to select is the longest, and that where one side is much shorter than the other two it should never be chosen. A limit* is laid down for the discrepancy permissible between azimuths carried through the tertiary work and the azimuth of the secondary line.

Computation of Third Order Co-Ordinates.—In the computation of the positions of the third order points it is assumed that the measurements are made, not on the spheroidal earth, but on the plane projected surface. The azimuth taken for the computation of the latitude and departure is therefore the map azimuth, that is, the azimuth measured from the direction of x, not from north. The difference between the map-azimuth and the true azimuth is the convergence of meridian, given by the formula on page 276.

In the course of the work it was found desirable to carry the computation of latitude and departure along every line of the adjusted third order triangulation for the sake of checking the computation. In this way, starting from one second order point we obtain co-ordinates for two others. These co-ordinates will not agree exactly with those got from the second order work, the discrepancy being due in part to errors of observation and in part to the projection. The discrepancy is distributed by estimation among the third order points, care being taken that an excessive amount of adjustment is not put in any one line. Experience has shown that it is undesirable to begin adjusting until after all the computation checks have been satisfied.

Computation of Fourth Order Triangulation.—As the Cadastral Survey neared completion and accordingly precision became of greater importance in comparison with speed, it was decided to increase considerably the number of triangulation points to the square kilometre. This was done in the greater part of Sharqia and throughout Beheira by the introduction of a fourth order of triangulation, the positions of the fourth order points being determined by resection.

* The limit is $5'' \times \sqrt{\text{number of sides}}$.

It is well known that the position of a point can in general be determined uniquely by resecting three known points, that is, by observing the angles at the unknown point between the three pairs of known points.

A fourth point was also resected as a check on the observations.

The method of computation need not be described, since it is well known and is given in most manuals of surveying.

Traverse Computation.

As already explained in Chapter XIV, the traverse observations of the first part of the cadastral survey were reduced without the control afforded by triangulation. In the year 1898, however, part of Gharbia was being surveyed, and the hydrographic triangulation was employed in places to control the bearings of traverse lines, but the control was only partial, and applied to that particular feature of the work where errors would have least importance on the areas. There appears to have been no control of the chaining operations, which are the chief source of inaccuracy in traverse work.

In Giza, which was surveyed in 1898–9, thifs urther control was introduced, and in the Fayum the control was extended by the introduction of two classes of specially planned triangulation.

In Qaliubia and Daqahlia, control of the azimuths and, at a later stage of the work, of the lengths through the co-ordinates, was introduced, but the tradition of the village as the unit of traverse as well as of the detail survey persisted for some time. There was, consequently a tendency on the part of computers to calculate village boundaries first, and tie to triangulation points later. In Girga, the method of computing a direct traverse line joining each pair of triangulation points was introduced, and such lines were termed primary traverses. Those whose terminals were on traverse lines and not at triangulation points were termed secondary. At present no distinction between these two classes of lines is made in the field for cadastral work, but in town surveys it has been found advantageous to have the primary lines observed first by special observers with more elaborate methods, and then the secondary lines, and as a consequence of the experience so acquired, a similar arrangement will shortly be introduced into the cadastral traverse.

One of the first steps taken after the control by triangulation was started was to lay down definite limits for the permissible difference

between traverse and triangulation. The table of permissible differences was based on the investigation given by Jordan * which leads to the following tables of maximum errors in angle and in chaining :—

MAXIMUM ERROR ALLOWABLE IN THE CLOSURE OF THE ANGULAR MEASUREMENTS.

Number of angles ...	2	4	6	8	10	15	20	25	30	35	40
Error allowable	2′·1	3′·0	3′·7	4′·2	4·7	5′·8	6′·7	7′·5	8′·2	8′·9	9′·4

MAXIMUM ERROR IN CHAINING.

Sum of the sides.	MAXIMUM ERROR.		
	Good ground.	Average ground.	Bad ground.
metres.	metres.	metres.	metres.
200	0·32	0·39	0·45
400	0·49	0·60	0·69
600	0·65	0·79	0·92
800	0·80	0·98	1·13
1,000	0·95	1·16	1·34
1,500	1·31	1·61	1·86
2,000	1·67	2·05	2·36
2,500	2·03	2·48	2·88
3,000	2·39	2·92	3·38

The first depends on the formula for the maximum error in angle, $m = 1'{\cdot}5\sqrt{n}$, where n is the number of angles measured.

And the second on the formula, $m = \sqrt{\alpha^2 l + \beta^2 l^2}$, where α and β are constants varying with the character of the ground, and m is the maximum permissible error in a length l. †

It will be observed that in adopting these limits, which are in use in European surveys, it was considered that Egyptian surveyors working under proper supervision would be capable of turning out work up to European standards. The result has entirely justified

* "Handbuch der Vermessungskunde," 6th edition, Vol. II, pp. 75 and 439, (Stuttgart 1904).
† For further details, see pp. 377-8.

this opinion formed in 1900. When the angular control is based on the fact that the sum of the angles of a polygon must satisfy a certain geometrical condition, and on the modification of this condition employed when the bearings and lengths of traverse lines are checked by triangulation, it is found that less than six per cent of the traverse lines fail to reach the standard. This is satisfactory, but the fact that six per cent do require re-observation emphasizes the necessity for careful supervision, without which it is certain that this percentage would be considerably increased to the detriment of the precision.*

From a discussion of the discrepancies of chaining in six hundred lines selected at random throughout Egypt, it is found that the probable *accidental* error of chaining is $0{\cdot}0032\sqrt{l}$ metre, where l is the number of metres in the line.

During the years 1901–6 work continued at extraordinarily high pressure, and the computation office was not the least sufferer in this respect. Consequently, there was little opportunity of introducing improvements into the methods. In 1906, however, every portion of the work was critically examined and somewhat more stringent regulations for supervising the computations were drawn up. In particular, rules clearly defining the amount of error that could be distributed by the computer were laid down, so that risk of serious error through bad judgment was eliminated.

These rules all depend on the principle that a point may be plotted to 0·1 of a millimetre and the position of two points with respect to each other can be measured to 0·2 of a millimetre on the map, *i.e.*, 0·5 of a metre in nature when the scale is 1 to 2,500. This critical examination resulted amongst other things in an increase of the number of triangulation points per square kilometre by the introduction of a fourth order of triangulation and the enunciation of a rule that practically amounts to division of the ground into half-kilometre squares by the traverse net-work. The outstanding lessons of the traverse computation are :—

(1) That the number of points of control (triangulation points) must be adequate;

(2) The desirability of a criterion for rejecting ill-braced traverse;

* The failure to reach the standard is in nearly all cases due to gross errors, not to the accumulation of a number of small errors owing to want of adequate care.

(3) The necessity for an adequate number of traverse points. This rule depends altogether on the interpretation to be placed on the word "adequate." Adopting the above definition of the precision with which lines may be measured, we have arrived at the somewhat empirical rule that the traverse route (l) between two points should not exceed four times the shortest distance (s) between them plus 500 metres or in symbols :—

$$l \not> 4\,s + 500$$

(4) The necessity for placing limits to the amount of adjustment permissible. These limits may be extended according to the accuracy demanded, but in any case they should not be omitted, and this is the more urgent, the less skilled the class from which computers are drawn.

The actual procedure in traverse at present will be described below. It is the outcome of some ten years of experience, and is found to give satisfactory results in Egypt, however details might have to be modified in other countries with different staffs and different geographical conditions.

The traverse section is now organized in nine sub-sections as follows :

(1) Clerical sub-section ;
(2) Checkers of field-books ;
(3) Checkers of the closure of polygons ;
(4) Copyists ;
(5) Computers of azimuths;
(6) Multipliers ;
(7) Checkers of multiplication ;
(8) Computers of general co-ordinates ;
(9) Computers of map-sheet (local) co-ordinates.

1.—It is found convenient and really economical to have a special clerical sub-section for this branch of the office, whose duties consist in receiving field records, keeping them till actually wanted, and in keeping tally of their movements until they are no longer required in the office, when they may be sent to the general store of documents.

2.—On being received for computation, the field-books are at once examined to see that all means have been accurately calculated and written in ink, that all alterations have been duly initialled and that there are no doubtful figures likely to lead to delay at a later stage.

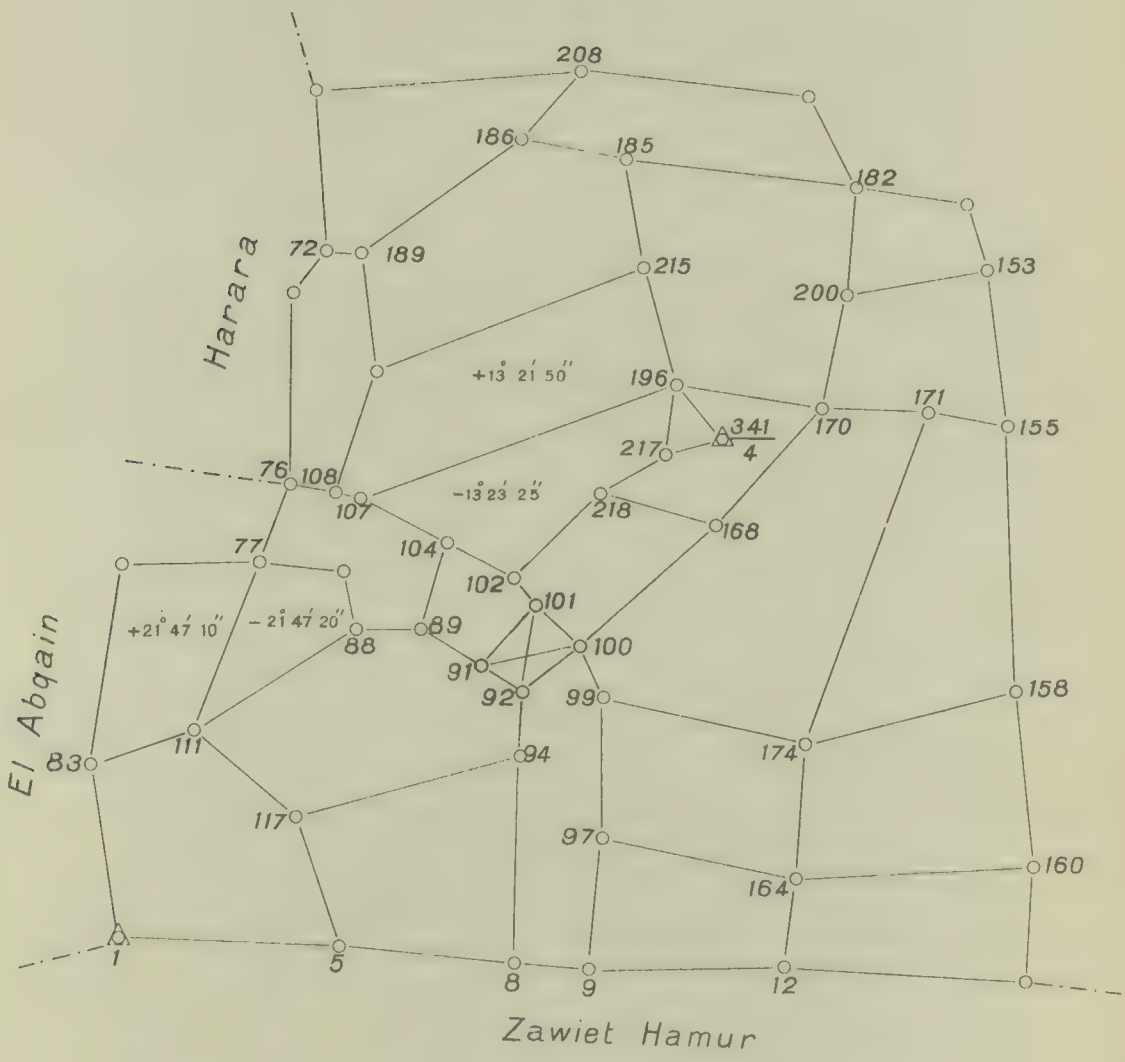
3.—As soon as possible, while the traversers are still in the neighbourhood of a village, the interior angles of all its traverse polygons are added and compared with the theoretical sum, viz., the excess of twice as many right angles as the figure has sides over four right angles. It is at this stage that the sketch (see Plate XVI) is found useful. Should inspection show that the angular observations in any line are not of sufficient precision to satisfy the table on page 283, a re-traverse of the angles of the line is requested. When all the polygons close with sufficient precision, the field-books and sketches are passed to the next section.

4.—Here the means of the field observations are entered on the computing forms (see specimen below, columns 1, 2, 3). It is of some importance to have a special section for this work, since the routes to be followed are by no means matters of indifference. The computers first select main traverse lines from one triangulation point by the shortest route to an adjoining one, then subdivide the rough triangles thus obtained by secondary traverse lines, endeavouring so to arrange the work that short tie lines are not left over to the end.

5.—The chief of the traverse section is supplied with lists giving the azimuths of all lines of the triangulation, and the co-ordinates of all points. At the head of the column, the azimuth of the line observed by the traverser is entered. Then addition of the interior angle $\pm$ 180° gives the bearing of the traverse line as seen at the second station, and the same procedure is followed along the traverse to its end. If the line has passed the third sub-section, the closing azimuth will in general agree well enough with that of the triangulation line observed at the end, but now inadmissible angular errors may be revealed. No error exceeding that laid down in the table on page 283 may be exceeded. If the errors are admissible they are distributed equally among all the angles. The distribution of errors in the specimen given is shown by the small figures in column 3.

6.—We have now the observed lengths (S) and the azimuth (α) with respect to the x-axis of the co-ordinate system, and we want the products $S \cos \alpha = \delta x$ and $S \sin \alpha = \delta y$. These are worked out with the help of Jordan's Opus Palatinum, a table of sines and cosines for every 10″, admitting of direct use without interpolation, and the actual multiplication is performed on the Brunsviga machine. The computers have mechanical rules for arriving at the signs of the incre-

LOCATION OF BAD OBSERVATIONS IN TRAVERSE.



Survey Dept. Cairo 1908. (356-85)

ments, and the positive and negative increments are entered in separate columns.

(7).—The multiplications are then checked by independent computers, using traverse tables in place of the sine and cosine tables.

(8).—The algebraic sum of the positive and negative increments of x and y should be equal to the corresponding increments between the two terminal points of the line. The differences are considered to be due to the line under computation alone, and if the closing error, defined to be the actual distance between the terminal point as already determined and its position given by the traverse line, does not exceed the limits of permissible error laid down in the second table on page 283, the errors are distributed. This is done by allotting to each product an apportionment of the correction proportional to its length. These corrections are printed in small figures in columns 6, 7, 8 and 9. If the error is too great, an examination is made to ascertain that this is not due to faulty distribution of previous traverse lines, and if not, the line is sent for re-traverse, with an indication of the probable position of the error, where this can be deduced. It may be mentioned that alterations in field-books, even where highly probable, are strictly forbidden.

When the corrections have been apportioned, the co-ordinates of each point are found by adding algebraically the increments to those of the preceding point.

(9).—The co-ordinates thus computed are then prepared for plotting by transferring the origin to the south-west corner of the sheet on which the respective points will fall.

Lists giving the general co-ordinates of all the corners of sheets that fall on one sheet on the scale of 1 to 10,000 are supplied, the calculation having been made by interpolation from co-ordinates computed for the corners of sheets on the scale of 1 to 50,000. It is thus easy to see by inspection within what sheet a given point will fall. The sheet co-ordinates (including those of the sheet-corners), together with the number of the sheet on which each point falls, are then entered in lists which are supplied to the plotting section of the office, where the points are plotted on the blank plane-table sheets, for use in the detail survey.

Traverse Computation.

Traverse No. (6)

Province Beheira — District Delingat.

Point.	Measured Distances S	Ang of Direction α. Ang. of Polygon β. Correction.			S Cos. α. Correction.		S Sin. α. Correction.		x Corrected. ±		y Corrected. ±		Names of Villages.	
					+	−	+	−					On Left.	On Right.
		°	′	″	Metres.	Metres.	Metres.	Metres.	±	Metres.	±	Metres.		
87														
		345	36	29										
88									+	98,297·32	−	47,589·24	Line No. 12. in Zorafa	
		91	10	56										
		−		9										
89	78·74	256	47	16		18·00		76·66	+	98,279·40	−	47,665·85		Part of the inside line No. 12. Nehiyet Zorafa.
		124	58	45		− 8		− 5						
		−		9										
90	76·44	201	45	52		70·99		28·35	+	98,208·49	−	47,694·15		
		145	35	19		− 8		− 5						
		−		10										
91	67·85	167	21	01		66·20	14·86		+	98,142·37	−	47,679·24		
		162	40	26		− 8	+ 5							
		−		10										
92	70·73	150	01	17		61·27	35·34		+	98,081·18	−	47,643·85		
		155	39	19		− 8	+ 5							
		−		10										
86	189·24	125	40	26		110·35	153·73		+	97,971·01	−	47,490·02	Line No. 12. in Zorafa	
		033	03	07		− 18	+ 10							
87		−		10										
Total	483·00	338	43	23		326·81	203·93	105·01	−	326·31		99·22		

105·01

098·92

The permissible error is 0·68

Differences 0·50 0·30

Plotting the Map-Sheets.

The Co-Ordinatograph.—It is hardly too much to say that the whole system would have failed, and something less accurate or much more expensive would have had to be substituted, if there had not been available an instrument by which the points fixed by the network of traverse could be plotted on the field-sheets rapidly and without loss of precision. This instrument is the co-ordinatograph, designed and constructed by the firm of Coradi of Zürich. It consists essentially of a scale carried on a bracket which is perpendicular to, but movable along another fixed scale. The steel beam carrying this second scale is clamped rigidly to the drawing-board on which the map paper is pinned (see fig. 16). The mobility of the bracket is secured by mounting it on three wheels, one of which (R) rolls on the drawing-board or on a special guide-rail B, laid on the paper, according to the pattern of the instrument. The other two *r*, *r*, are bevelled and run in a slot cut parallel to the scale on the beam A. The axles of the bevelled wheels are coned and rest in conical bearings in the ends of antagonizing screws, to admit of slight adjustment in the line of the axle. The object of this adjustment is that the scale on the moving bracket may be set accurately perpendicular to that on the fixed beam. On the moving bracket runs a carriage borne on two bevelled wheels that run in a slot in the bracket, and a third running freely on the rear rail of the bracket. In this way, every point rigidly attached to the bracket has only one degree of freedom, viz., parallel to the scale on A, and every point rigidly attached to the carriage has only one degree of freedom relative to the bracket, viz., parallel to the scale on the bracket. Thus if the carriage is free it has two degrees of freedom, viz., movement in two perpendicular lines parallel to the plane of the paper.

Fig. 16.
Plan of Co-ordinatograph.

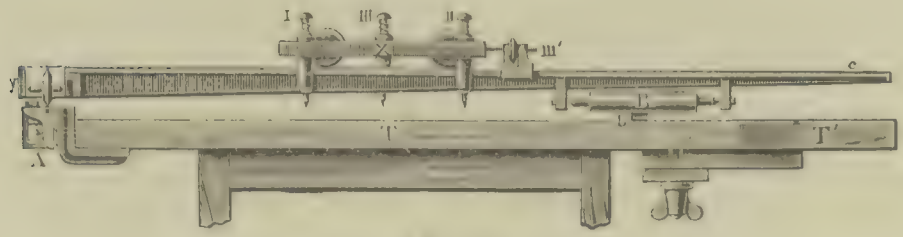


Fig. 17.
Co-ordinatograph ; detail of the bracket.

The framework of the bracket carries a clamp *m*, by which it may be rigidly attached to the beam A, and similarly the carriage may be fixed by a clamp, not shown in fig. 16, but as *m'* in fig. 17. The edges of the scales are bevelled at an angle of about 45°, and the bevelled edge is cut into a fine rack, with 40 teeth to the centimetre. A corresponding pinion wheel engages in the teeth, and has on the same axis a graduated wheel measuring fractions of a revolution of the pinion. Attached to the framework is a pointer which indicates on the scale engraved on the beam or bracket respectively the larger divisions, but to provide for change of origin, the numerical values of these divisions are not engraved on the scale, but are printed on a linen tape movable parallel to the scale by rolling and unrolling on two small drums C, C, C', C'. The larger divisions of the measurement are thus indicated on the beam or bracket scale and the smaller ones on the vernier wheel. A means of fine adjustment is provided in the slow motion screw (*m*, fig. 18) on the clamp. The carriage has three sockets (*u*, *u*, *u*, fig. 18), fixed perpendicular to the plane of the paper, in which may be dropped plotting needles (I, III, fig. 18), or a drawing pen (II, fig. 18). The handles of the needles or the pens are turned and polished so as to fit truly in the sockets without lateral play. The needle point is kept off the paper by a spring, and may be protected from breakage, when not in use, by a cap (*h*, fig. 18). A slight pressure with the finger on the top of the needle (I), will impress a fine puncture in the paper, to represent the point plotted. The distance between the sockets I and II corresponds to a change of origin of 20 centimetres, and III corresponds to a double change of origin of 10 and 20 centimetres respectively.

The circumference of the pinion wheel is one centimetre divided into 40 teeth. Thus, one revolution of the wheel corresponds to a lateral movement of one centimetre in the frame. If now the engraved divisions are not 10, but 4 millimetres apart, and if we so number the tape divisions and the vernier wheel subdivisions that each division is called 10, then we may plot metres directly on to the paper on the scale of 1 : 2,500 without arithmetical reduction. For 1 division = 4 millimetres.

= 1 / 2,500 of 10 metres,

and the subdivisions are also numbered accordingly. It is estimated that in this way the instrument has saved annually the expense of

at least one computer, who would otherwise have had to be engaged to reduce co-ordinates from metres to the scale of 1 : 2,500.

There is a further great advantage in the fact that it is not necessary to transform the co-ordinates from the general axes of the system to the axes formed by the sheet lines. All that is necessary is to calculate the co-ordinates of sheet-corners on the same projection, and transform all the co-ordinates of points plotted on that sheet, to an origin in the south-west corner of the sheet. The sheet-lines are then drawn in by hand, instead of by the instrument.

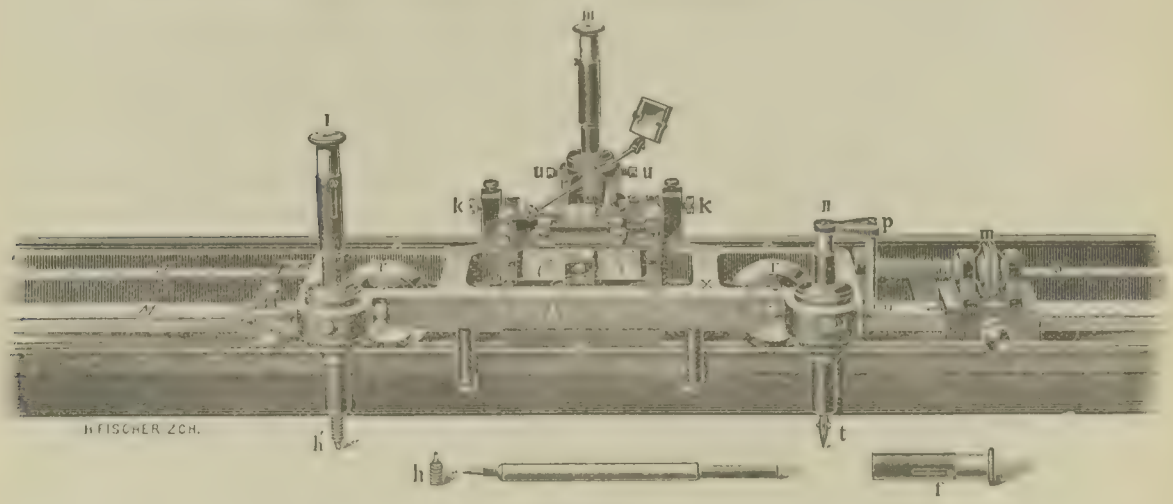


Fig. 18.
Co-ordinatograph ; details of carriage.

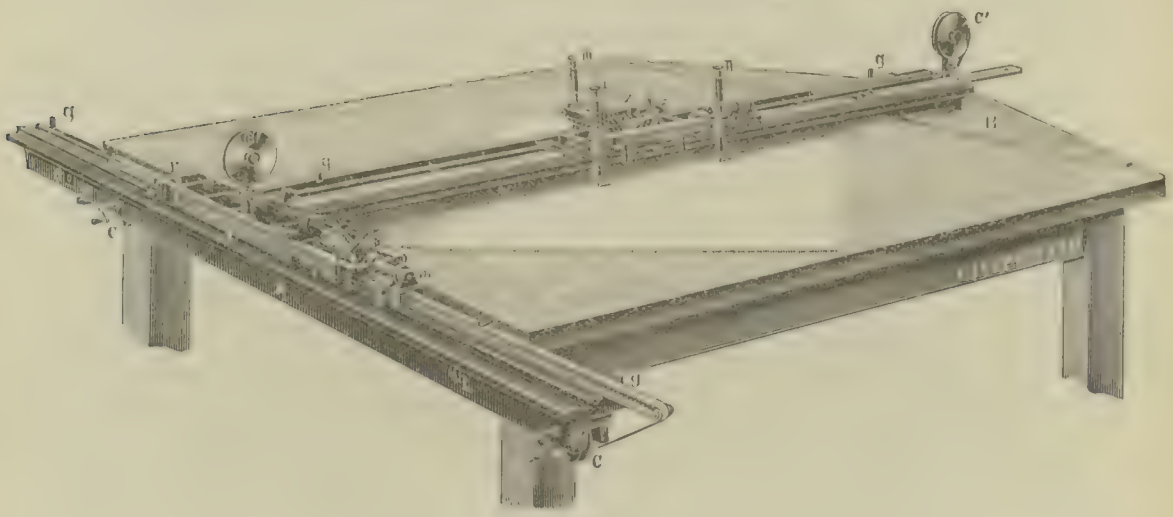


Fig. 19.
Co-ordinatograph ; general view.

By a simple arrangement, the two pinions* and two graduated wheels are carried on the same axle, so that two scales may be utilized on the same instrument. The corresponding large divisions are engraved on different parts of the beam and bracket, at about one centimetre apart, and the linen tape has the numbers corresponding to the two different scales on its right and left halves respectively, so that it has to be re-wound at each change of scale. It is impossible, from lack of space, to describe the various refinements introduced, and further information, if desired, should be sought in the maker's pamphlet descriptive of the instrument.

Practically the only adjustment that is likely to get out of order is that of perpendicularity between the scale on the bracket and that on the beam. The instruments at Giza are tested at the commencement of work every week, usually by plotting a square of about 50 centimetres side, and measuring the diagonals.

If the figure is a rhomboid of side a, and diagonals d_1 and d_2, then it is easily seen that the error from perpendicularity, ε, is given by the equation:

$$\sin \frac{\varepsilon}{2} = \frac{d_1 - d_2}{2a\sqrt{2}}$$

It is, in this way, easy to adjust the instrument so that ε is under 60″ in which case $d_1 - d_2$ will be less than 0·2 millimetre.

So useful was the instrument found, that in 1902 a second one was ordered, and in 1905 a third, which served rather as reserve in case either of the others became unavailable. On receipt of the third the first was returned to the maker for a general overhaul. On its return, some trouble was experienced with it, as it did not appear to be plotting correctly, and the fault was traced to a slight vertical flexure of the bracket, which it had doubtless received in transport. This fact emphasized the necessity for checking lengths plotted by the instrument more frequently than was done up to then; accordingly the adjustment is now checked every week by plotting points at intervals of 10 centimetres in the two fundamental directions and checking them with a steel scale which has been carefully standard-

* In some instruments there is only one pinion.

ized at Helwan Observatory. Since each instrument may have two scales, those in use here have the following scales in pairs :

1 : 1,000 for general plotting ;
1 : 2,500 for plotting cadastral maps ;
1 : 800 or 1 : 8,000 } for plotting town maps and some topographical maps for subsequent photographic reduction to the scales of 1 : 1,000 or 1 : 10,000.

It is of course clear that a mere change of the decimal point of the co-ordinates will admit of the instrument being used for any scale which is a multiple or sub-multiple by a power of 10 of the principal scale.

The method of using the instrument for cadastral purposes is as follows. The traverse section prepares lists giving the co-ordinates of the four sheet-corners, and each traverse point in the sheet or just outside the boundary. Using these co-ordinates, the plotting section plots the sheet-corners and all the traverse points, surrounding each with a faint circle in pencil, and writing against each the corresponding number of the point.

As soon as the sheet is finished, it is removed and the dimensions are checked before it has time to shrink. A copy is then plotted on tracing-paper and the field-sheet checked by it, so that errors of plotting may be detected.* This done, the sheet-lines are drawn in black ink and the traverse lines in blue ink, after the lengths of the latter have been checked against the original chained lengths. This is the final check on the computation and few significant errors can escape detection in this way. There is, however, one special class of error that cannot be detected in this final measurement, namely, errors amounting to a small displacement of a point of a line that runs either north and south, or east and west, in a direction perpendicular to the general length of the line. The accuracy of such lines can only be assured by special care in computing and plotting them, and by checking by tie-lines in the field.

As regards the rate of work, it has been found possible for four men working two instruments, to plot twice over as many as 600 points in a day of seven and a half working hours, or at the rate of 80 points an

* It is now found that a satisfactory and more rapid check is obtained by plotting every point twice before removing the paper from the co-ordinatograph.

hour, and this rate has been maintained for several weeks at a time under the pressure of urgency, but in general the rate does not exceed half this.

Shrinkage. — Much difficulty has been experienced in dealing with the alteration of the map-sheets under the varying meteorological conditions to which they have been subjected. Paper is a highly hygroscopic substance; and in damp weather it absorbs moisture from the air and expands, and gives it up in dry weather with consequent contraction. After the process of manufacture, paper is generally packed with a certain excess of moisture which its confinement in bales prevents from evaporating. It is then in so damp a condition that its use immediately is almost impracticable, and it is much improved by being dried in open frames in the open air. This practice has now been followed for the past six years, since, that is, work in the dry climate of Upper Egypt compelled attention to this point. The effect, to judge from the diurnal behaviour of a measured sheet, depends on the relative and not the absolute humidity, for a sheet plotted in the morning when the air is relatively damp will be found shorter in the dry afternoon, to return to its original size on the following morning. There is also an annual effect of the same kind, the sheets being shorter in summer and longer in winter; and superposed on this there is a slow secular shrinkage which is rapid at first, but much slower afterwards. Consequently, it is advisable to dry the paper during a period of about three weeks at least and as much longer as may be possible. It has been found that the paper shrinks more in length than in breadth.

In spite of this precaution, however, it is almost impossible to dry paper so thoroughly at Giza that it will not afterwards shrink when exposed to the full strength of solar radiation under field conditions. Many attempts have been made to get rid of this tendency altogether; various kinds of paper, some specially submitted as quite unshrinkable by firms anxious to be allowed to tender for the supply, and others subjected to special treatment in the way of artificial drying, have been tried, but hitherto without entire success. It would satisfy a great want to be able to procure a paper that could be relied upon not to alter to an appreciable extent, for not only does it cause trouble in checking lines, which may have been correct when first

plotted, but it leads to delay in adjusting the continuation of details from one sheet to an adjoining one, which may have been plotted at a different time and have shrunk differently; in distributing error of shrinkage among the different pieces of a line the total length of which is known; and in finding areas from measurements made on the map. Some of these difficulties recur when the maps have to be autographed for printing, especially when, as frequently happens, the part of a sheet belonging to one village has to be completed by drawing in the part belonging to another, which may have been surveyed on a sheet where the shrinkage is different. These difficulties are overcome by distributing divergences of length obtained by direct chaining from those measured on the map in each traverse polygon, so that there is no danger of accumulated error being carried forward in this way. In autographing the maps, the field-sheets are brought, as nearly as possible, to their original dimensions by slight damping, and much of the difficulty is thus disposed of.

It remains to describe the method adopted to allow for the shrinkage, in computing areas graphically from the maps. This was based on the facts that the sheets are nearly square, and the shrinkage is usually under 6 or 8 millimetres on a sheet of about 440 millimetres length. Since the sheets are nearly square, shrinkage in length produces the same effect in altering areas as that in breadth, and the total effect may be found by adding together the shrinkage in each direction. The effect on areas of different sizes was computed and tabulated, and was applied as an additive correction when the sheet had shrunk and a subtractive correction in the very rare cases where the sheets had expanded. In practice, a value as high as 8 millimetres has been found for the combined shrinkage in length and breadth and this gives corrections of 470 or over 2 per cent., a quantity that is far from negligible. The average total shrinkage was about half of this, giving corrections of about 1 per cent. The utility of the method and the necessity for applying some correction were thus manifest.

Measurement of Areas.

All areas were measured on the maps and controlled by computed areas of villages. The procedure was as follows:

First each plot was measured with the computing scale; the sum of all the plots in a hod was next compared with the area of the hod

as found by planimeter; finally, the sum of the areas of the hods in a village was compared with the village area calculated from the traverse boundary of the village.* At each step, limits of differences, whether between the area then found and the sum of the areas found in the previous step, or between the first and second measurements of the area in that step, were laid down. It will be convenient to give a more detailed account of each step in reverse order.

The area within the traverse polygon that followed the village boundary as closely as possible, was computed as follows:—

If x_n, y_n; x_{n+1}, y_{n+1} are the co-ordinates of two points P_n and P_{n+1} and if M_n and M_{n+1} are the feet of the perpendiculars on the axis of x, then the area $M_n\ P_n\ P_{n+1}\ M_{n+1}$ is $M_n\ M_{n+1} \times \frac{P_n\ M_n + P_{n+1}\ M_{n+1}}{2}$

or analytically $(x_{n+1} - x_n)\frac{y_{n+1}+y_n}{2}$ ... ... (1)

Similarly, the area of the next piece will be—

$$(x_{n+2} - x_{n+1})\left(\frac{y_{n+1}+y_{n+2}}{2}\right)$$

and so on.

So long as one point is to the north of that which preceeds it, $x_{n+1} - x_n$ will be positive; but when the traverse point at the extreme north of the village boundary is passed, x_{n+1} will become less than x_n and the difference will become negative, so that this element of area becomes subtractive. If, then, one begins at the extreme south point and proceeds by east to the north point of the boundary, it is clear that the sum of the elements of area will be positive, but that when the north point is passed, the sum of the elements of area between the western boundary, the extreme ordinates and the axis of x will be subtractive. But if this area is subtracted from that between the eastern boundary, the extreme ordinates and the axis of x, the result is the area inside the traverse boundary. Thus, by forming all the products similar to (1) for successive pairs of points, and summing them round the circuit of the village boundary, we have the area inside that boundary.

* The average area of a plot was about 2·5 feddans and of a hod about 80 to 100 feddans.

Expressed analytically:

$$2\,A = \Sigma\,[(x_{n+1} - x_n)\,(y_{n+1} + y_n)] \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

This formula may be written—

$$2\,A = \Sigma\,\Delta\,x_n\,(y_{n+1} + y_n)$$

and since y_n will occur twice, once in the element $\Delta\,x_{n-1}\,(y_n + y_{n+1})$ and once as above, we may write the formula in the form—

$$2\,A = \Sigma\,y_n\,(\Delta\,x_n + \Delta\,x_{n-1}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

In exactly the same way we may find the alternative formula—

$$2\,A = \Sigma\,x_n\,(\Delta\,y_n + \Delta\,y_{n+1}) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Both of these formulæ have been used to compute the area, so that the one serves as a complete check on the accuracy of the work by the other. The computing form was arranged as is shown below.

It should be noticed that any line parallel to the x-axis may replace the latter, and any parallel to the y-axis may replace it, without affecting the area, so that by subtracting suitable numbers from both x and y, the products may be kept of a reasonable magnitude.

The successive values of y_n were written in column (1), and those of x_n in column (4). In columns (2) and (5) the values of $\Delta\,y_n$ and $\Delta\,x_n$ are entered, and in columns (3) and (6) the values of $\Delta\,y_{n+1} + \Delta\,y_n$ and $\Delta\,x_{n+1} + \Delta\,x_n$ respectively. In the last four columns are entered the products of the numbers in columns (3) and (4) and columns (1) and (6) respectively. The products are summed and the totals carried forward to the next page of the computation. Finally, on arriving at the point from which a start was made, the algebraic sum of the products in the penultimate double column should be numerically equal to that in the last double column. If not, some mistake has been committed. The sum gives twice the area in square metres. It is reduced to feddans by dividing by 4200·83, and the area sent confidentially to the inspector under whose charge the village in question is being surveyed. A sheet showing the traverse route followed in computing the area is attached.

The sums of columns (2), (3), (5) and (6) should be zero, which gives a control on the accuracy.

In 1906 several cases of discrepancies occurring in very large villages were investigated, and as the result, it was decided no longer to send village areas, but to adopt the map-sheet as the largest unit for the control of area measurements. The true dimensions of the map-sheet being known, it is a comparatively easy matter to find the area in

nature represented by it. The above method of working is accordingly only adopted now in a few isolated cases.

Traverse Area Computation.

Primary. H. F. Cemetery, Mohafza Cairo, Qism el Waili.

Point.	(1) y_n	(2) Δy_n	(3) $\Delta y_{n+1} + \Delta y_n$	(4) x_n	(5) Δx_n	(6) $\Delta x_{n+1} + \Delta x_n$	Products. (3) × (4) +	Products. (3) × (4) −	Products. (1) × (6) +	Products. (1) × (6) −
1	0000			0000						
		+ 051			− 017					
2	+ 051		+ 063	− 017		− 018		1071		0918
		+ 012			− 001					
3	+ 063		+ 027	− 018		− 008		0486		504
		+ 015			− 007					
4	+ 078		+ 037	− 025		− 017		0925		1326
		+ 022			− 010				4400	
5	+ 100		+ 056	− 035		+ 044		1960		
		+ 034			+ 054					
6	+ 134		+ 062	+ 019		+ 042	1178		5628	
		+ 028			− 012					
7	+ 162		+ 051	+ 007		+ 043	0357		6966	
		+ 023			+ 055					
8	+ 185		− 018	+ 062		+ 074		1116	13690	
		− 041			+ 019					
9	+ 144		− 119	+ 081		+ 029		9639	4176	
		− 078			+ 010					
10	+ 066		− 111	+ 091		− 004		10101		264
		− 037			− 014					
11	+ 033		− 066	+ 077		− 091		5082		3003
		− 033			− 077					
1	000	+(051)	+ 018	000	−(017)	− 094				
Sums...		+ 185	+ 314		+ 138	+ 232	+1535	−30380	+34860	−6015
		− 185	− 314		− 138	− 232	2 A = 28845		2 A = 28845	

14,422·5 square metres = 3 Feddans 10 Qirats 10 Sahms.

Measurements of hods.—A hod consists of a number of contiguous plots of land of as nearly as possible the same quality. The average area is about 80–100 feddans, and it thus forms a convenient sub-

division of the village, especially as village areas vary between extremely wide limits. On the map a hod of 80-100 feddans, if square, would have a length and breadth of about 23-26 centimetres, which is of a convenient size for planimetric measurement. This fact has been made use of, and every hod has been measured and compared with the total area of the individual plots that compose it, and with the area of the village of which it forms part. There is thus a doubly controlled check on the accuracy of the plot measurements which so far as the surveyor is concerned, are the ultimate object of the survey.

The planimeter is too well-known an instrument to require description here, but it may be stated that the special form of the polar planimeter constructed by Coradi, of Zürich,* has been found very satisfactory. It admits of the movable arm being used on both sides of the polar arm, which has the advantage of giving a compensation for non-parallelism of the axis of the roller and the movable arm, for it can be shown theoretically that, if the required area is measured once with the pole on the right and once with it on the left, the error due to this non-parallelism changes sign and so disappears from the mean of the two measurements. To take full advantage of this compensation, the planimeter must be as symmetrically disposed as possible with respect to the area to be measured, in the two positions.

In actual use, the instrument was set for the scale 1 : 2,500 or 1 : 4,000 as the case might be, so that one unit of the vernier, 6·4 or 6·25 square millimetres on the map, represented respectively 40 or 100 square metres in nature. Each instrument was checked with the special radius provided which enabled accurately known areas to be measured, every day on which it was used, and, if necessary, was properly adjusted. The regular use of the radius for checking the adjustment of the planimeter is important when unskilled computers have to be employed, for it gives the Inspector a measure of the instrumental error, and so enables him to detect readily indifferent work on the part of the computer. If, using the radius, the average difference between the results with the pole to the right and to the left is, say, 1 per thousand, an examination of the third column in the computing form (see the example below) will show whether the computer is adding materially to this difference by following incorrectly the boundaries of the figure

* Compensation Planimeter.

which he has measured. In the example quoted below, the first two measurements are of a lower precision than the last two, although the mean happens to be identical. When necessary, the Inspector may form an arithmetical estimate of the computer's precision by taking out the mean or probable errors of his work and allowing for those of the instrumental adjustment. The hod area was taken out four times in all as follows :—

Direction of integration.	Position of the pole of the instrument.
Clockwise	To right
"	" left
Counter-clockwise	" "
" "	" right

The means of the first two and of the last two observations will be free from the error referred to above : the mean of all four will tend to be free from error of slip. An example showing the form used and results obtained follows :—

Number of hod.	Readings.	Value in units.	Means.	Area.		
				Fed.	Qir.	Sah.
16	1,325 6,410 1,308 6,408 1,892 6,987 2,543 7,633	5,085 5,100 5,095 5,090	5,092 5,092	48	11	16

The same hod would afterwards be measured by another computer under such precautions that the second would be unable to know the result obtained by the first, and the two results compared by the superintending engineer. If they agreed within one per cent., the mean

was accepted ; if not, a re-measurement was made, and so on. A correction was then applied for the shrinkage of the paper, and when the area of the hod had been satisfactorily determined, the total of the individual plots was compared with it. If the total agreed within one per cent. with the planimetric area, the result was accepted.

The total area of all the hods in a village was then found, and compared with the area inside the village traverse boundary. If they agreed within one per cent., the result was accepted, but if not the inspector instituted an investigation into the discrepancy. The cause was generally found to lie in a misunderstanding with regard to the actual traverse boundary followed in computation. As mentioned above, a sketch removes all ambiguity.

Measurement of the Plots.—The rapidity with which the survey had to be executed and the necessity of making maps in order to avoid omissions or overlapping of records, prevented the adoption of any ssytem of mensuration on the ground, and compelled the substitution of a system by which the areas were measured on the maps. This work was all done in the offices of the taftishes, but the account of the methods adopted falls most naturally in the category of computation, and is accordingly included in this chapter.

Previous to 1901, plot areas were measured with the " feddan comb." This apparatus, which is much used by the Revenue Surveys of India, consists of a stiff cardboard open frame about 21 × 17 centimetres outside dimensions and 14 × 8 centimetres inside dimensions. At intervals of 5 millimetres, close to the long sides of the opening, small dots are printed, through which fine black threads, running in parallel lines from side to side of the opening and thus dividing it into a series of strips of equal breadth, are drawn. When placed over a plot to be measured the threads divide it into strips of the breadth of 5 millimetres representing 12·5 metres on the ground. The sum of the average lengths of all the strips in a plot will therefore measure the area of the whole.

The average lengths are stepped out with dividers, and the sum of the lengths measured on a diagonal scale which is printed on the cardboard. The unit of this scale is 5·6 millimetres, corresponding to 14 metres on the ground. Thus the area represented by a strip of unit length is 14 × 12·5, or 175 square metres, which is one twenty-fourth part of 4.200 metres (a feddan), or is one qirat. The diagonals divide the scale into twelfths, giving areas to two sahms.

The weak point about the feddan comb is that it is almost impossible to keep the threads tight and parallel. Further, to thread them through the exact positions is difficult and the dots are not always placed at the correct distances apart, which may be due to shrinkage of the cardboard after printing. In one specimen chosen at random from those formerly in use in the Department, these disadvantages were such, that errors amounting to one twenty-fifth part of the area in the case of small areas would not infrequently occur, although the fractional amount of the error would decrease almost in proportion to the size of the plot, and for large plots would be very small. In this case, however, other sources of error would begin to produce appreciable effects, and accordingly it was decided in 1901 to replace the feddan comb and dividers by a computing scale with a reticule ruled on tracing paper. The principle involved is the same, but the computing scale itself carries a scale of the proper size and a vernier so that areas are read off at once without the use of the diagonal. The only sources of error are the expansion and contraction of the tracing paper carrying the reticule, and those due to the small errors of measurement or of judgment in estimating the irregular pieces at the boundary of a plot. The latter are probably to a large extent compensating, but the former source is more serious and should be taken into account if the method is to be utilized to the best advantage. This would best be done by making a small table of corrections depending on the average error of the breadth of a strip and applying these to the areas as measured. It has been found by experience that there is less alteration in the reticule if it is lithographed on the tracing paper without damping the stone or the paper, and celluloid sheets with an etched reticule have advantageously been substituted for paper during the last few years.

The procedure actually employed by the local field-parties was to measure each plot by two computers independently and to compare the results by a third. A table was drawn up giving the limiting discrepancy admissible in the two measurements, according to the size of the plot. If the difference fell within the limit allowed, the mean of the two was accepted; if not, the area was measured a third time and the third result compared with the other two, and if two of the three agreed within the permissible limit, their mean was accepted. The following table, condensed from that actually employed by the field-parties, shows the extent to which discrepancy was admitted.

Columns have been added giving these differences as percentages also. It should be borne in mind in this connexion, that the probable error of the mean of the two observations is only one-third of the discrepancy. Plots of over ten feddans are now measured with the planimeter as already described for hod-measurements, or are subdivided for measurement, and very irregular plots also are measured with the planimeter.

Area.	Discrepancy allowed.			Probable error per cent.
	Absolute.		Percentage.	
Feddans.	Qirats.	Sahms.		
1	0	16	2·8	0·9
2	1	4	2·5	0·8
3	1	16	2·3	0·8
4	2	4	2·2	0·7
5	2	8	1·6	0·5
10	3	4	1·3	0·4

From the mean area of the plot a correction, taken from a table was applied to allow for the shrinkage of the paper. The corrected result was then recorded in the Land Register as the area of the plot.

When all the plots forming one hod had been measured, the sum of their areas was compared with that found for the hod by planimeter and if the two values did not differ by more than one per cent, the measurement of the individual plots was considered satisfactory. If not, the matter was investigated and the discrepancy cleared up.

CHAPTER XVI.

The Chain Survey.

All the foregoing operations of the verification of standards, base-measurements, triangulation of the second, third and fourth orders, and theodolite traverses have had for their object the provision of a large number of points on the ground of which the relative positions were accurately known. These served as a control to the field-measurements and prevented errors from accumulating until they reached a magnitude which would be appreciable on the scale employed in the maps. When the present survey was commenced no maps existed which showed boundaries of villages or even those of districts, and the province boundaries on the maps of the hydrographical survey were but approximations. The surveyor had therefore to obtain all his information on the spot, and when village boundaries lay in uncultivated land they were only identified with considerable difficulty. A line of traverse points was supposed to follow the village boundary, but it was less easy for the traverser to locate it since he was not concerned with ascertaining the limits of individual properties and therefore took the line indicated by the "dallal" or sheikh without much investigation.

In one respect this portion of the work differs very markedly from the operations that have already been described. Not until the measurement with the chain of the holding is commenced does the surveyor come in contact with the landowner.

Triangulation points are often fixed on private land, and traverse points are placed along the margins of fields, but these operations are not immediately connected with the individual holding, at least not in the public opinion.

As soon as the property of the inhabitants of a village is delimited, measured or recorded, a new set of difficulties arises. Previously, opposition or ill-will might cause some delay to the triangulator or the traverser, but now the work could not proceed at all without the active co-operation of the villagers; and though this was not usually difficult to obtain, as they welcomed a definite location and assessment

of their lands, still they had no special motive for pushing on the work with rapidity. It was not easy to ensure the attendance on any day of all the owners of the plots which would probably be measured, and the absence of one or two often prevented the settlement of matters relating to neighbouring holdings Frequently the owners declined to attend, saying that the "dallal" would indicate their boundaries, having all the time the intention to present complaints afterwards if they considered that his indications did not correspond with the lands which they possessed or which they claimed. Indeed, it was everywhere a common practice to pay but little attention to the first measurement and to reserve information for the re-measurement when the complaint was being investigated; this habit arose principally from the idea that more individual attention would be gained during the investigation of a complaint than in the measurement of property in the general survey. It is not necessary to point out how much this increased the amount of work which had to be done in order to complete the survey of the country.

The absentee owners gave even more trouble, for they frequently did not attend in order to point out their boundaries, but sent a copy of their title-deeds which they requested might be followed. In the majority of cases it was almost impossible to do this, for the description of the property was always vague, and usually those who were named as the neighbouring proprietors had long been dead and their land had been subdivided in passing into other hands; some had encroached on the property and had probably been long in occupation, and with such cases neither the surveyor nor the survey inspector had any power of dealing authoritatively.

In large villages it was very difficult to say exactly when any particular area would be measured up, and doubtless it was highly inconvenient for owners to be kept waiting for several days before their land was recorded. Nevertheless in very many cases they took but little trouble to facilitate the work and the representatives whom they sent often had neither knowledge of the property nor of its boundaries. The case of a large landowner who owned land situated not more than two hours by train from Cairo where he lived, was by no means an isolated one; he requested the Survey Department to remove those who had, as he was informed by his bailiff, encroached upon his property, but he himself had not visited it for fifteen years.

To complete a given area in a given time under these circumstances was no easy matter, and the moment arrived in the survey of each village when the books had to be closed and any outstanding questions had to be settled on the basis of information furnished by the sheikhs of the village, leaving the owner who was thereby prejudiced to complain later to the Ministry of Finance, to which the land-registers were transmitted. It must be remembered in this connection that no legal authority existed by virtue of which the Survey could require landowners to attend or to produce documents and title-deeds. Work had begun in 1892 as a verificatory survey of State lands carried out by the order of the Ministry of Finance, and this gradually developed into a cadastral survey. A decision of the Council of Ministers dated June 16, 1898, appointed the Director-General of the Survey Department on its formation, but conferred no powers on those who had the carrying out of the work. Ministerial circulars of November 1899 and 1901 laid down certain requirements which were designed to facilitate the work of the Re-assessment Commissions, but the Survey had to execute the cadastre without the support of any decree or legal provision. That it was possible to carry out the work at all rapidly under such conditions was due firstly to the general desire for something more definite than the frequent partial re-measurements which had long been a burden, and secondly to the fact that the methods of work were quickly improved until a very satisfactory standard of accuracy was reached wherever sufficient information of a reliable character was given.

The extent to which the land is subdivided has already been alluded to, and the average number of plots of different sizes is an important factor in determining the best method of work. It will also be a matter for serious study in any scheme of land registration which may be introduced. For this reason a classification by size has been made, and in the following table the total number of plots in each district have been divided into three classes and the percentage of the number in each class to the whole is given more fully than on page 30. The classes are:

1) Under 12 qirats, or 2,100·4 sq. metres or 2,512·1 sq. yards.
2) 12 qirats to 5 feddans, or 0·21 to 2·1 hectares, or 0·519 to 5·19 acres.
3) Over 5 feddans, or 2·1 hectares, or 5·19 acres.

The data are only given for the provinces which were surveyed after 1898, for no statistical records were kept before that time.

Size of Plots in Lower Egypt.

Province.	District.	Total number of plots.	Plots under 12 qirats.		Between 12 qirats and 5 feddans.		Above 5 feddans.		Remarks.
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	
Qaliubia ...	Dawahi Masr ...	4,830	1,667	34·51	2,522	52·22	641	13·27	
	Nawa	25,976	9,589	36·91	14,545	56·00	1,842	7·09	
	Qaliub	18,146	4,652	25·64	11,677	64·35	1,817	10·01	
	Tukh	40,427	16,452	40·70	21,849	54·06	2,126	5·24	
		89,379	32,360	36·20	50,593	56·60	6,426	7·20	
Sharqia ...	Miniet el Qamh ...	35,659	12,557	35·21	20,409	57·24	2,693	7·55	
	Belbeis	36,159	15,995	44·24	18,029	49·86	2,135	5·90	
	El Zagazig	39,501	15,008	38·00	20,269	51·31	4,224	10·69	
	Kafr Saqr	31,340	9,181	29·29	17,032	54·34	5,127	16·37	
	Hehia	21,923	7,939	36·21	11,580	52·82	2,404	10·97	
	Faqus	37,593	16,193	43·07	16,434	43·71	4,971	13·22	
		202,180	76,873	38·02	103,753	51·32	21,554	10·66	
Daqahlia .	Simbellawein ...	35,828	9,397	26·23	21,725	60·64	4,706	13·13	
	Aga	25,073	6,542	26·09	16,248	64·81	2,283	9·10	
	Mit Ghamr	35,813	10,672	29·79	21,769	60·79	3,372	9·42	
	El Mansura ...	25,192	7,662	30·41	15,360	60·97	2,170	8·82	
	Damietta	11,149	3,473	31·15	5,606	50·28	2,070	18·57	
	Dekernes	51,092	20,634	40·39	26,692	52·24	3,766	7·37	
		184,147	58,380	31·70	107,400	58·32	18,367	9·98	
Gharbia ...	Fua	5,805		22·74		51·77		25·49	For 1 village.
	Dessuq	22,183		23·64		49·54		26·82	„ 17 villages.
	Zifta	37,305		26·90		68·67		4·43	„ 32 „
	El Burollos	3,741		22·09		68·67		26·74	„ 2 „
	Tanta	58,680		26·31		67·28		6·41	„ 48 „
	Santa	39,845		33·45		63·03		3·52	„ 29 „
	Talkha	13,769		10·45		54·02		35·53	„ 2 „
	Sherbin .. .	14,927		18·71		42·02		39·27	„ 18 „
	Kafr Zayat ...	35,025		22·76		69·04		8·20	„ 13 „
	Kafr el Sheikh ...	42,879		15·15		64·95		19·90	„ 4 „
	Mahalla Kobra ...	26,892		20·17		68·38		11·45	„ 57 „
		271,019		25·31		64·46		10·23	
Menufia ...	Tala	58,361		35·16		60·47		4·37	For 56 villages.
	Ashmun	41,951		35·14		61·00		3·86	„ 32 „
	Menuf	64,429	22,156	34·39	40,743	63·24	1,530	2·37	
	Shibin el Kom ...	59,181	22,194	37·50	35,681	60·29	1,306	2·21	
	Quesna	38,005	10,499	27·62	25,178	66·25	2,328	6·13	
		261,927		33·96		62·25		3·76	
Beheira ...		Under re-survey.							

Size of Plots in Upper Egypt.

Province.	District.	Total number of plots.	Plots under 12 qirats.		Between 12 qirats. and 5 feddans.		Above 5 feddans.		Remarks.
			Number.	Percentage.	Number.	Percentage.	Number.	Percentage.	
Aswan... ...	Aswan	10,931	5,629	51·50	4,373	40·00	929	6·50	
	Edfu.	21,438	7,702	35·92	12,050	56·21	1,686	7·87	
	El Derr...	6,370	2,086	32·75	2,729	42·84	1,555	24·41	
		38,739	15,417	39·80	19,152	49·44	4,170	10·76	
Qena	Deshna	39,119	16,017	40·95	21,073	53·87	2,029	5·18	
	Esna.	23,816	10,678	44·84	11,600	48·71	1,538	6·45	
	Luxor	22,002	9,719	44·17	10,191	46·32	2,092	9·51	
	Naga Hamadi. ...	47,414	17,679	37·28	26,712	56·34	3,023	6·38	
	Qena.	31,746	13,018	41·00	16,863	53·12	1,865	5·88	
	Qus...	36,508	15,272	41·84	19,037	52·14	2,199	6·02	
		200,605	83,383	41·58	105,476	52·57	11,746	5·85	
Girga... ...	El Baliana	39,736	16,845	42·39	20,584	51·80	2,307	5·81	
	Akhmim..	23,724	8,668	36·53	14,085	59·37	971	4·10	
	Girga	46,717	16,584	35·50	27,025	57·85	3,108	6·65	
	Sohag	48,048	20,175	41·99	26,218	54·57	1,655	3·44	
	Tahta	59,454	22,646	38·09	33,933	57·10	2,875	4·81	
		217,679	84,918	39·01	121,845	55·98	10,916	5·01	
Assiut.. ...	Manfalut.	40,655	17,564	43·20	20,695	50·91	2,396	5·89	
	Mallawi...	33,853	13,991	41·33	17,509	51·72	2,353	6·95	
	Abnub	37,608	15,691	41·72	20,361	54·14	1,556	4·14	
	Deirut	41,370	16,863	40·76	21,828	52·77	2,679	6·47	
	El Badari	22,678	9,399	41·44	12,118	53·44	1,161	5·12	
	Assiut	39,177	16,729	42·70	20,790	53·06	1,658	4·24	
	Abu Tig...	36,542	11,873	32·49	22,726	62·19	1,943	5·32	
		251,883	102,110	40·54	136,027	54·00	13,746	5·46	
Minia... ...	Abu Qirqas	19,176	7,796	40·66	9,520	49·64	1,860	9·70	
	Beni Mazar	23,252	9,246	39·77	11,536	49·60	2,470	10·63	
	El Feshn	18,587	7,666	41·25	8,920	47·99	2,001	10·76	
	Maghagha	21,096	8,151	38·64	11,129	52·75	1,816	8·61	
	El Minia..	20,836	7,823	37·55	10,642	51·07	2,371	11·38	
	Samalut...	20,587	5,971	29·00	11,171	54·26	3,445	16·74	
		123,534	46,653	37·76	62,918	50·94	13,963	11·30	
Beni Suef...	Beni Suef.	41,758	15,075	36·10	23,282	55·76	3,401	8·14	
	El Wasta.	39,205	16,990	43·33	19,795	50·50	2,420	6·17	
	Beba.	51,045	26,603	52·12	22,048	43·20	2,394	4·68	
		132,008	58,668	44·45	65,125	49·33	8,215	6·22	
Fayum.. ...	El Fayum	39,469	18,444	46·73	18,881	47·84	2,144	5·43	
	Etsa..	40,080	15,655	39·06	21,072	52·57	3,353	8·37	
	Sennures..	45,576	20,412	44·79	22,473	49·31	2,691	5·90	
		125,125	54,511	43·57	62,426	49·89	8,188	6·54	
Giza	Embaba...	35,287		29·94		62·19		7·87	For 37 villages.
	Giza..	17,675		27·78		63·00		9·22	„ 26 „
	El Saff	21,311		33·14		61·45		5·41	„ 27 „
	El Ayat...	26,896		47·42		47·14		5·44	„ 16 „
		101,169		33·64		59·36		7·00	

Thus it will be seen that about 40 per cent. of the plots are under half-a-feddan and only about 7 per cent. are over five feddans in size. Moreover, many of these plots are owned in shares by two or more owners, which increases the complexity of the question. The proportion of shared plots has lately been taken out for the province of Sharqia and in it 26 per cent. of the holdings were shared, there being on the average three owners to each plot so shared. In other provinces the proportion is higher, see p. 320.

From 1897 onwards, the surveyor was provided with a map-sheet on which were plotted the points that had been fixed by the traverser. The distances between the points were also furnished to him as well as a descriptive list of the points for purposes of identification.

Since 1898 the points have been placed at a maximum distance of 500 metres apart and the different traverse-lines are seldom as much as 700 metres from one another, so that the area within which the surveyor was required to locate the detail with the aid of the traverse points seldom reached a quarter of a square kilometre. As the land was invariably flat and the topographical features were few, this presented no difficulty even to those who had had but a short training in surveying with the chain.

The instruments used were :—

a 20-metre steel chain of No. 8 B. W. G. steel wire ;
a cross-staff with tripod stand ;
a plane-table, 50 centimetres square with tripod stand and canvas cover ;
a boxwood ruler scale having a scale of 20-metre chains reading to tenths on one edge and one of "qassabas" on the other ;
an off-set scale and a chain-book.

The 20-metre chain had replaced the 5-qassaba chain used in the State lands survey, but it was at first made of wrought-iron wire and was therefore easily lengthened by the stretching which it experienced during work. Steel wire chains were introduced in 1898.

The plane-tables were no longer used in order to fix points by intersection but rather as portable drawing-tables on which the measurements taken in the field were plotted at the time. At first the engineers were equipped with plane-tables and alidades which they used in checking the chain-survey, and in replacing traverse points which had been removed or lost ; but later when the traverse was controlled by triangulation the positions of the traverse points were much more

accurately determined, and graphical triangulation with a plane-table would have introduced work of greatly inferior accuracy; it was therefore forbidden. Missing points were to be replaced by chaining from at least three other points, or were to be provided by re-traversing the line. Offset lines laid out by eye were as a rule very inaccurate, so that cross-staffs had almost always to be used. The tendency however, was to use them for longer lines than their accuracy justified, and at first the maximum length up to which offsets were taken was two chains.

The measurements of holdings, etc., were plotted with a 30-centimetre plotting-scale of the ordinary pattern, but the edges of these were found to chip so readily in the hot, dry summer weather that a shorter and thicker pattern was adopted in 1902.

At first all such measurements were plotted directly on the map, not being otherwise recorded, but this sometimes entailed the work having to be done afresh if the map was lost or damaged, so that in 1898 chain-books were used whenever necessary and from 1903 were regularly employed for entering all the measurements taken which were also plotted on the maps.

The length of the chain was controlled during work by comparing it carefully with a 20-metre length laid down with a steel tape* on a level piece of ground close to the village; two wooden pickets were driven into the ground and small nails were placed in them to mark the exact distance. Having assured himself of its correctness the surveyor next proceeded to verify the reference points with which he had been provided, and his first operation was to check the position of the traverse points with the descriptive lists by measuring the distance between each in order to see if any had been removed. These, if few, were replaced by others, of which the position was determined by chaining from the other points, or if many were lost new traverse lines were run with a theodolite. Next the collection of buildings which occupied the village site was surveyed and plotted on the map; this being an untaxed area the internal detail of lanes, alleys, open spaces, etc., was not shown on account of the time available being

* These tapes are compared with others which are used only for such comparisons, and have been standardized at the Helwan Observatory.

insufficient to allow of the numerous additional measurements being taken which were necessary for accurately representing it. The outline of the houses which were situated on the margin of the village was plotted, and the space within it was hatched to indicate an area occupied by buildings and untaxed, but no further detail was shown. In the provinces now under revision all streets, lanes and open spaces are shown, since rapid work is no longer so all-important a consideration, and it is desirable to supply more detail especially in the large villages, since it will be many years before the Town Survey staff are likely to map them. (See Plan XXVII)

The village site being finished, chain-lines were next measured from one traverse point to another, and secondary lines from one such chain-line to another so as to cross a series of plots near their ends. As has been already stated, the great majority of plots are more or less rectangular in shape, and are usually long in proportion to their breadth. These can be effectively surveyed by measuring the breadth of each on a line intersecting the plots near one extremity and on another line near the other extremity, and subsequently joining the corresponding points so obtained. Irregular plots, or those having curved boundary lines, were surveyed by similar chain-lines, offset measurements being taken to the boundary line or to the feature which was being represented. A meandering watercourse or a canal having numerous bends was surveyed by fixing points along it by measuring lines to each of them from two or three points on the nearest chain-lines, and then employing the points so fixed to control other lines which would be near enough to the curved boundary to allow of offsets being used. Canals, roads and other topographical features were easily surveyed in this manner, but the plots could not be delimited without further information being obtained, since the boundaries are not marked in such a manner as to be readily recognized, dressed-stone marks are very rarely seen and a rough lump of stone forms a very doubtful guide to the precise angle of a plot. At the present time a landowner is not obliged by law to mark the corners of his property, so that holdings can only be surveyed correctly if the owner, or his representative who is acquainted with the boundaries, is present at the time of survey in order to point them out. In plan XXVIII a facsimile is given of a cadastral map-sheet as it is prepared in the field. Plan XXIX shows the same sheet in the form in which it is published.

In villages where the land is under perennial irrigation the difficulties are much less as crop succeeds crop on the same area and the little surface channels (*misqa*) which lead the water on to the sown land tend to remain unchanged and so form to some extent a topographical boundary. In lands which are flooded by the annual inundation, however, these water-channels do not exist and plots are arranged in apparent disorder throughout the basin (see Plan VIII). Every village has its "dallal," or measurer, who measures up the land of the inhabitants as they require and where the land is annually inundated he lays out the plots again as soon as the mud is dry enough to sow upon. His work is comparatively light in areas of perennial cultivation but in the basin lands of Upper Egypt where the land has to be set out in plots annually, with the aid of the cadastral records of 1854–59 A.D. (1272–77 A.H.), he is a person of considerable importance in the village.

This absence of definite boundary-marks greatly facilitates the encroachment of one proprietor on the land of another. Where both are resident in the village, the error is usually discovered when the land-register is read out to the inhabitants as soon as it has been compiled, for each man is then told the area which he has been recorded as occupying. In the case of absentee landowners, however, this safeguard is not effective and their lands may be considerably diminished without the officers of the survey being able to ascertain if such is the case. The former land-registers which were kept in the Mudiria offices, showed the amount of land that each landowner possessed at each rate of tax, but they seldom stated exactly where such land was situated, though occasionally the name of the hod might be mentioned, but even this amount of information was rarely given. It might, therefore, happen, and in fact did happen now and then, that the lands of an absentee landowner were divided up amongst the principal inhabitants, and an area, equal to that which was recorded as belonging to him, was pointed out to the Survey on the margin of the desert, where the soil was greatly inferior to that on the river-bank where perhaps his property really was. A year or two later the taxes of the village would be re-assessed but this would tell him nothing, as the tenant usually pays the tax and remits the balance of the rent to the owner. Not until the lease, which is usually for a period of three years, had expired did the owner discover what had happened, and only then

because the rent offered for a renewal of the lease was much less than that which he had hitherto been receiving. The Survey officials had no certain means of detecting such cases for the area owned by many of the inhabitants was found to be less than that which had been recorded in their names, since it had hitherto been computed by the old Coptic methods. Encroachments, therefore, did not necessarily appear as excesses when the land was measured. No large-scale maps of any province then existed, and consequently the true position of each property could not be checked, so that usually all that was known was that it was included in the lands of such and such a village.

When the systematic measurement of all the holdings in a village was about to be undertaken, a notification was posted in it for the information of the landowners. This was not sufficient to warn those who did not reside in the village, for it was often to the interest of the tenant not to inform his landlord that the survey of his lands was about to take place.

From the autumn of 1898, therefore, the survey of a village was always advertised in the "Official Journal" directly it was commenced. This journal has, however, but a limited circulation, and the public press does not quote extensively from it, and did not consider the survey of village lands as being of sufficient interest to give it much publicity, so that the absentee landowner was frequently a sufferer.

A further effort to assist him was therefore made in 1900 when the practice was instituted of sending by post the following written notice of survey to all landowners who did not reside in the village and whose postal addresses could be obtained:—

Survey Form No. 57.

SURVEY DEPARTMENT.

——— SURVEY OFFICE.

To

You are hereby notified that the survey of the village of

District ——————————— will be

commenced forthwith, and you are requested to attend or to depute a representative to see that your lands are correctly recorded.

(*Signature*)

INSPECTOR.

Date

This removed their disability to a great extent, but not wholly, for sometimes their addresses were not obtainable, at other times they were insufficient, and often the tenant possessed a written authority to receive all such communications and consulted his own interest by not forwarding the notice to his landlord, part of whose land he had probably pointed out as his own. Frequently, too, the landowners themselves gave little if any assistance in the attempt to record accurately the property of private individuals, as has already been explained.

The practice of reading out the land-register in the village when completed furnished a control on its correctness for those who lived there, but was of no assistance to others who resided elsewhere; they had perhaps already attended to point out their boundaries and found it inconvenient to attend again at the end of the work; moreover, in the course of later investigations and in the final compilation of the registers their original indications may have been found incorrect. Not only was it unjust to them to close the land-registers under these circumstances, but the risk was incurred of very numerous complaints being lodged with the Mudiria when the revised areas were inscribed in the next tax-receipt, and the staff there available for their investigation was neither sufficiently numerous nor fully competent to deal

with extensive measurements. From the end of 1901 therefore the system was introduced of communicating the result of the survey of each proprietor's land to him in the form here given :—

(TRANSLATION) S. FORM No. 59.

SURVEY DEPARTMENT.

Village, **Qassassin el Sebakh** *District,* **Kafr Saqr**

Name of actual occupier, **Ibrahim Effendi Ali**

	Feds.	Qir.	Sahms		
	3	22	20	Temporary Tax.	Area of property as originally recorded.
	15	11	2	Final Tax.	
	19	9	22	Total.	
	1	10	14	From registers of other villages.	Additions to original area :—
	0	16	14	Bought.	
	3	15	8	Mortgage foreclosed.	
+	25	4	10	Total.	
	5	15	18	Entered in registers of other villages.	Deductions from original area :—
	2	12	0	Sold.	
	9	12	0	Mortgage foreclosed.	
—	21	12	16	Total.	
	3	22	20	Temporary Tax.	Area found on survey.
	17	20	15	Final Tax.	
	21	19	11	Total.	
	5	4	19	Excess.	Difference due to transfer of land from Public Domain.
	—	—	—	Deficit.	

If not satisfied with this result you must send your complaint to ... ... Inspectorate situated at ... ... within a period not exceeding ... ... days from this date to be investigated on ... ... at the village in your presence or in the presence of your delegate who must be empowered to sign for you. Any petition after the above date must be sent to the Mudiria.

Whenever a landowner has land in more than one "hod" the area in each "hod" is now stated on the back of the notice to assist him in understanding the result.

Where the landowner's address could not be obtained the notice had to be given to his tenant, and in such cases it not infrequently did not reach its destination; but on the whole the system gave the proprietor a means of knowing how his land had been recorded and the explanation of any change that had been made. The number of complaints was greatly increased by the invitation to lodge them for examination, but a certain number of errors were thereby rectified. Another object in facilitating the presentation of complaints was that the practice of surveyors demanding payment for measuring land lest it should be wrongly recorded was most difficult to check, since neither party would testify to it. Though it was very common, complaints of it were extremely rare, even though inquiries were made and notices were posted in every village stating that the work of the Survey would be carried out gratuitously. The only means which seemed likely to prove effective was to render the correction of inaccurate work as accessible as possible by facilitating complaints, but the small landowner still seems to fancy that his security is greater if he pays, and he neither realizes nor believes that the checks employed to control the work of the surveyors are quite as efficacious if he on his part will co-operate.

Another source of complaint was that in Upper Egypt the land-registers had sometimes to be closed before the river was at its lowest, and therefore before the surveyor had been able to measure the whole of the riparian lands. Thus anyone who owned property in this part of the village was recorded as owning a smaller area than he really did. The extremely rapid rate of work which was unavoidably maintained in order to supply two provinces a year for re-assessment of their land-tax, was responsible for this, and especially the rule that the re-assessment of a province had to be completed and the revised rates of tax published before the 31st of December; this necessitated closing the registers of each village at the earliest possible date, whether the river was at its lowest level or not.

The most fertile source of error lay, however, in plots which were owned by two or more proprietors who had not located their respective portions but owned it in shares. Since there was no boundary to be actually measured on the ground, there was no means of verifying the statements made, and the amounts in any case were usually small so that the total owned by anyone in the village might be not much altered by a mistake in recording the part-owners in one or more

plots. Thus it was easy for some of these part-owners to arrange that the names of others should be omitted, especially if they happened to be absent from the village at the time of survey. Recent investigation shows that as many as 80 per cent. and often more of the complaints against the Survey were due to the omission of the names of such part-owners from lack of information or from their intentional suppression. These were sent in after the survey was finished and when the area of properties found by it were being used in collecting the land-tax.

Complaints of incorrect measurement were not numerous, for the control by the traverse points was in most cases adequate and in places where more were needed it was easy to fix them by chaining.

Landowners at times complained that their lands were recorded as "Public Utility" or "State Property," and the surveyors had often much difficulty in deciding how some of the roads and canals should be described since the existing registers were both ambiguous and incorrect. The rules followed, and the special kinds of difficulty met with are described in the next chapter which deals with the compilation of the land-registers.

All such complaints which were received after the land-registers were closed were sent to the Mudiria for investigation by the staff of land-measurers there, but they had no training in modern survey methods and employed the ancient methods of computation so that the final result was not always an improvement. When the measurement of most of Upper Egypt had been completed it was possible to detach some of the Survey staff to take up this work in the provinces of Girga, Assiut, Minia and Beni Suef where such complaints were very numerous. The following tables show statements of these up to November 30, 1908, distributed under separate headings :—

Complaints Investigated after Survey.

Provinces.	Total No. received up to Sept. 1908	Complaints investigated.	Error in			Relating to		Unfounded.
			Survey.	Area.	Registers.	State Lands.	Former Registration.	
Assiut	8,388	5,311	24	230	3,540	161	—	1,356
Girga	3,539	2,699	20	19	1,567	21	38	875
Beni Suef ...	1,872	201	—	—	—	9	—	192
Sharqia	135	65	8	1	28	—	5	13

In one respect it was unfortunate that it had not been the practice from the commencement to refer all such cases to the Survey for re-investigation, for as soon as this work was undertaken the principal causes of the complaints were evident, and steps were taken to prevent their occurrence which have been to a large degree successful.

In Sharqia province, which has been revised in 1907 and 1908, written statements were taken from part-owners in every divided plot, setting forth the names of those who had shares, the proportion in which they were held, and other information; this involved a large amount of extra work, but since inaccuracies in recording this form of ownership accounted for 80-90 per cent. of the complaints which were received after survey, as already mentioned, this labour was fully justified.

The number of plots so shared is very large, as may be seen from the following table, which refers to Sharqia province:—

PLOTS OWNED IN SHARQIA PROVINCE.

	District.	Number of villages.	Total number of plots.	Number owned in shares.	Number of shares.	Percentage of shared plots.	Average number of shares per plot.
SHARQIA.	Belbeis...	56	35,835	9,684	26,684	27	2·8
	Mina el Qamh ...	82	34,933	10,143	30,568	29	3·0
	Zagazig	61	29,105	8,412	24,840	29	3·0
	Kafr Saqr	49	16,958	4,016	11,338	24	2·8
	Hehia	46	15,285	1,854	11,750	12	6·3
	Faqus	40	28,569	8,919	24,754	31	2·8

This degree of subdivision is by no means exceptional, as may be seen from the following data, which refer to the sharing of holdings in different parts of the country. In some cases all the villages of a province have not been included since the registers were not accessible when the information was being collected.

Plots Owned in Shares.*

Province.	District.	Total number of plots.	Number of plots shared.	Percentage of plots shared.
Aswan	Aswan... ...	4,815	1,961	41
	Edfu	21,458	9,204	43
Qena	Qena	31,851	12,360	39
	Esna	23,616	7,451	32
	Nag Hamadi.	39,584	13,278	44
Girga	Girga	46,740	23,700	51
	Tahta	59,475	31,171	52
	Akhmim ..	23,712	12,432	52
	Baliana	38,675	14,770	38
	Sohag	48,622	21,528	44
Assiut	Deirut... ...	27,933	10,837	39
	Abu Tig ...	36,542	22,618	62
	Mallawi ...	33,853	11,152	33
	Abu Qirqas...	17,176	9,926	52
Minia	Minia	21,130	10,392	49
	Maghagha ...	20,996	7,481	36
	Beni Mazar...	23,312	8,537	37
	Fashn	18,589	7,825	42
Beni Suef	Beni Suef ...	41,758	7,355	18
	Wasta	39,205	4,165	11
Fayum	Fayum... ...	39,469	12,008	30
Giza	Giza	17,670	6,612	37
	Embaba ...	34,472	14,169	41
	Mansura ...	25,208	7,140	28
Daqahlia	Simbellawein	36,253	9,746	26
Menufia	Shibin el Kom	39,374	12,964	33
	Tala	36,459	13,400	37
Gharbia	Dessuq... ...	22,183	6,940	38

* Communicated by Messrs. Skill, Campbell, Ahmed Bey Taufiq, Dray, and Dowd.

After checking his chain and his reference points the surveyor's first duty on taking up the survey of a village was to locate the boundaries of the village and then to proceed to measure and to plot on the map the holdings. This location of the village boundaries was not usually a complicated matter, since the village in which the owner of a piece of land paid his tax, and the omda under whose jurisdiction he was, furnished evidence, which could usually be depended upon, to show the village in which the land should be inscribed. The traverse lines followed as nearly as was convenient the village boundaries, so there was at times a tendency on the part of the traverser to pose as the authority who fixed the boundary or who would alter it to suit the view of this or that local authority, and since no map existed on which the boundary was shown, the pretension was often believed. It was, however, laid down in their instructions that boundaries of villages should be determined at the time of the chain-survey, for only then were all the factors available which had to be taken into consideration. Omdas naturally wished to increase the area of their jurisdiction; very small villages increased the number of registers to be kept up, and had their taxes already collected by the "sarraf" of the neighbouring village; long strips of one village projected from the main area, or lay wholly surrounded by the lands of another, the shifting of the river-channel not infrequently transformed a portion of a village at first into an island and then perhaps transferred it to the opposite bank; there were villages again of so large an area that it was a distinct hardship for the inhabitants of the more distant portions to journey to the chief village to pay their taxes, or for any other administrative purpose. In all these different conditions good reasons were to be found for modifying boundaries in order to gain greater simplicity or convenience, or to utilize well-defined features in place of vague lines across fields, but such changes were often unpopular. All proposals for the alteration of boundaries were examined by the Mudiria, and if found to be an improvement and not such as to arouse local opposition, were forwarded to the Ministries of Finance and Interior for their approval.

It frequently happened that the village areas which formed convenient units for taxation were too large for the purpose of public security, and smaller villages were recognized as units for this purpose. Usually, however, the boundaries of a taxation area were also

boundaries of units of public security, though one of the former might contain several of the latter. But since the boundaries of the taxation area alone were located on the ground, the recognition of a group of habitations as a separate village for purposes of public security only applied to the village and its inhabitants for their lands were not located separately nor was a boundary round them laid down. The land of Egypt, therefore, is divided up into the villages which are areas for the collection of land-tax, since the boundaries of these alone are mapped.

The next boundary of importance was that of the "hod" or the unit of tax-rate within the village. The limits of the old "hods" or "qibalas" were too vague and seldom fulfilled the requirements of the new conditions which had been laid down to facilitate the re-assessment of the land-tax.

It was only when the scheme for the re-assessment of the land-tax was being worked out that the necessity for a "hod" of small size came prominently into notice; the earlier surveying of lands in the provinces of Sharqia and Beheira by the State Lands Survey had followed the old "hods" which were then in use. When the re-assessment commissions commenced work, therefore, in these provinces, they had to subdivide the "hods" to form smaller ones fulfilling the conditions which had been laid down. These subdivisions were called Qism 1, Qism 2, etc., of the "hod." Afterwards the Survey was entrusted with the duty of delimiting the new hods, which demanded some care and a knowledge of land, for although the local authorities were supposed to indicate the subdivision, since they were thoroughly acquainted with the relative qualities of the land in different parts of the village, in practice they frequently could not or would not do so, and the survey engineer had to make the best arrangement that he could. These new "hods" were inspected by the Survey Inspector, but with the survey of 60 or more villages to superintend, maps to examine, and registers to check, as well as complaints to enquire into, he had but little time to devote to this work. The number of "hods" which were re-divided by the re-assessment commissions is given in the following table :—

Mudiria.	No. of Hods.	
	Divided.	Total.
Sharqia	363	1,876
Beheira	325	2,167
Gharbia	593	7,893
Giza...	155	1,994
Menufia	61	5,263
Fayum	199	3,781
Qaliubia	26	2,596
Daqahlia...	579	7,946
Qena...	53	4,599
Aswan	31	1,198
Girga	26	4,489
Assiut	154	5,866
Minia	135	5,287
Beni Suef	91	3,058
Total...	2,791	58,013

Since these hods were the areas on which the newly assessed rates of tax were fixed they have become of special importance, and in revising the cadastral maps of villages which have had their land-tax re-assessed the first operation is to locate these hod boundaries accurately and then re-measure the plots within them. Village boundaries are not now altered without special reasons and then whole hods are transferred if need be, but hods are not divided.

In surveying the plots the owner, or in his absence, the lessee, the "dallal," or the sheikhs point out the boundaries. In doing this some plots are met with which, though situated in village *A*, are recorded in the register of another village *B*, perhaps some kilometres away, in which the owner lives or has other property. This state of things was reported on by the Cadastre of 1878–1888 and its inconvenience alluded to.

It doubtless arose from the more influential landowners, who possessed land in various parts of the country, arranging to have it all recorded in the register of the village in which they lived for convenience in paying their taxes. Cases were met with in which a plot of ground when sold to a man in another village had been at once transferred to the land-register of that village. This custom had grown to large proportions, as may be seen from the following table:—

DETAILS OF LAND-TRANSFERS.

PROVINCE.	DISTRICT.	Number of villages.	Number of Landowners concerned.	Number of Plots transferred.	Area transferred in feddans.
QENA	Qena	20	3,316	2,645	6,732
	Nag Hamadi	31	—	3,551	11,913
GIRGA	Girga	60	12,207	—	19,024
	Tahta	60	—	—	35,301
	Akhmim	24	—	—	16,711
	Sohag	46	—	—	21,496
	Baliana	34	—	—	28,261
ASSIUT	Abu Tig	25	5,661	—	5,441
	Deirut	29	2,791	2,538	4,802
	Mallawi	31	1,517	—	4,606
MINIA	Beni Mazar	29	1,267	869	7,086
	Abu Qurqas	—	1,379	—	12,020
	El Fashn	—	890	—	7,837
GIZA	Giza	36	—	1,606	5,893
	Embaba	45	—	92	237
FAYUM	El Fayum	25	—	1,137	1,934
DAQAHLIA ...	Dekernes	24	-	704	2,295
	Mansura	64	-	551	3,464
	Simbellawein	83	834	1,088	5,004
MENUFIA ...	Shibin el Kom ...	38	2,456	2,045	3,259
	Tala	40	3,431	2,944	5,134
GHARBIA ...	Dessuq	37	564	651	18,015

The transfer of these isolated plots often delayed the surveyor greatly, for he could not balance the account of a proprietor's land until he received the statement of the area which was in another village, and some times in several other villages, in order to deduct it.

In several provinces which have the desert for one boundary, there were lands which had been granted to applicants under the provisions of the decree of 1884 authorizing Kharig el Zimam land which had not been registered in the previous cadastre to be so given. These lands had often been found unprofitable and abandoned, so that neither the limits nor the present owners were known. Whenever information was obtainable the land was included in the survey of the village in the ordinary way; where the owner had been lost sight of, the villagers usually wished the lands to be included within the village limits. In such cases the surveyor was instructed to lay down points in such waste land so that the "Kharig el Zimam" lands were included, and to record as Government property all such land which was not occupied or claimed.

Lands on the river margin which are gradually uncovered as the river falls necessitated special treatment. They are collectively termed "gezira" (island) lands and include not only islands lying in the stream but also all the lands situated between the high- and low-water marks. They have to be dealt with in a special manner since they are liable to be eroded by the river when in flood, and to be increased by deposition as the river falls. Consequently these lands are measured each year by the surveyors of the mudiria and the taxes are levied on each holder of such lands according to the area of which he is in occupation. As this amount varied from year to year according as erosion or deposition predominated, instructions were issued by the Revenue Department that "gezira" lands were not to be divided into plots on the maps but were to be treated as a whole area and the share of them owned by each man having property in the "gezira" was to be recorded. This plan would have worked well if it had been possible to wait until the lowest stage of the river before making up the land-register, in order to ensure that all the "gezira" lands were measured; but on account of the very restricted time limits laid down the land-register of every village had to be completed at the earliest possible date in order that it might be sent to the Ministry of Finance for the Re-assessment Commission and that the surveyor might take up another. This unavoidable omission of the low-lying "gezira" lands was the cause of numerous complaints against the Survey in Upper Egypt, which are to be attributed to the conditions of work imposed and not to any negligence in its execution. Recently,

in 1907, permanent marks have been placed on this class of land in Beheira province, to facilitate their annual measurement, and this will in time be carried out for the riparian holdings in other provinces. The holdings on such lands are now being mapped in all cases just as in other village lands.

The lands * which are collectively classed as "gezira" are divided into three categories, the "elu," the "murtafa," and the "mowati." The first of these includes the higher part on which a summer crop, such as cotton, as well as winter and flood crops, can be grown. This is rarely flooded and is practically the same in character as the general flood-plain of the valley, but being on the margin of the river, is liable to erosion. Of the other two classes, the "murtafa" is the upper land on which winter crops, such as wheat, barley, beans, etc., can be grown, since the flood has by December fallen sufficiently to allow of their being sown; the "mowati" is the lower land which is not uncovered until later and upon which, therefore, only cucumbers, marrows, melons and such ground plants can be grown.

In order to establish points which could be recovered annually after the flood had subsided, concrete blocks 40 cm. × 40 cm. and 50 cm. long were made by digging a hole of this size, lining it with boards and then filling it with concrete, a piece of angle iron being placed in the centre to mark the precise point; in this manner the line between the "elu" and the "murtafa" lands, and also that between the latter and the "mowati" lands were marked out, 421 marks being required for the riverain lands of 54 villages of Beheira province. The points being fixed, the lands were surveyed by the ordinary methods of chain-survey, and plotted to the scale of 1 : 2,500. The area dealt with was 4,897·5 feddans (2,057 hectares), of which 1,294·5 were of the "murtafa" and 3,603 of the "mowati" category.

The cost amounted to :—

	L.E.	MILL.
Field work...	312	269
Computation and compilation of registers	223	410
Travelling and transport...	90	907
Boat hire	22	925
Material for blocks	39	425
Total... L.E.	688	936

* This description is taken from a report on the demarcation of the Gezira lands of Beheira province by Mr. G. H. Morgan, of the Survey Department.

The field work took sixty-six days, and the whole of the maps and registers for the "gezira" lands of fifty-four villages were completed in one hundred and three days from the commencement of the field work. The number of these points has been since largely increased since the holdings in these lands are now mapped as those on other kinds of village lands.

Complaints.

Since it was extremely difficult to give sufficient publicity to the notification of survey to ensure that all the landowners in a village should know of it, it was necessary to give increased facilities for the correction of inaccurate measurement or of incorrect information which the surveyor might have received.

A very large proportion of the complaints were baseless, and others referred to matters which were not within the province of the surveyor, but on the whole they at times gave valuable information, although a very large amount of work had to be done in investigating numbers of baseless complaints as well as those which had some ground for their existence. These complaints also furnished a useful test of the work, for any carelessness or negligence soon produced an increase in the number of complaints and petitions sent in.

In 1900, registers were established in each inspectorate to record all complaints received, and the result of the investigation of each; these have been kept up regularly and furnish a complete record of all the complaints, petitions, etc., received in the Cadastral survey since then.

The results of those received during the last four years are analysed in the following tables:—

Summary of Complaints 1904–1907.

	1904.	1905-6.	1907.	Total.	Percentage.
Unfounded	6,574	28,464	4,035	39,073	78 %
Founded: Incorrect measurement...	341	2,141	568	3,050	6 %
Founded: Incorrect information supplied to surveyors...	721	3,662	1,268	5,651	11 %
Complaints awaiting investigation at end of year... ...	0	187	2,001	2,188	5 %
Totals...	7,636	34,454	7,872	42,962	–

Unfounded complaints comprise both those which were not substantiated on investigation, and those which concerned matters which were not within the competence of the Survey Department. The next table gives a classification of the complaints of the same four years showing the principal grounds of protest:—

Complaints referring to:	1904.	1905-6.	1907.
Recording in incorrect name	1,782	1,645	316
Shared plots *	189	267	174
Private land included in Public Domain...	108	171	108
" " " " State Lands	256	399	3,398
Alleged deficiency of land	3,989	28,553	540
Non-receipt of notice	88	884	181
Transfer to another village...	60	299	335
Information given by local authorities	168	235	742
Alleged excess of land...	261	385	155
Measurement in absence of owners	75	17	87
Incorrect boundaries	218	628	281
Sales, mortgages, or legal decisions	194	166	72
Transfers...	28	69	109
Survey employees...	70	291	168
Disputes between landowners	150	445	1,206
Total...	7,636	34,454	7,872

Recently the manner of investigation has been systematized to ensure that every complaint was examined in exactly the same way, which will not only improve the thoroughness of the enquiry, but also facilitated any re-investigation which might be necessary.

The most frequent complaint was that of a deficiency in the area recorded compared with that on which the owner had hitherto been paying tax. The usual cause of this was that his land had formerly been compute by the ancient Egyptian methods and was consequently shown as being larger than it really was; again, nearly everywhere the land-registers existing were those which were based upon records prepared about 1854–9 under Bahgat Pasha, and consequently before the length of the qassaba was fixed definitely at 3·55 metres. The lengths then employed were from 3·48 to 3·52 metres, so that areas measured with them were too large, since the feddan had been already

* Many more of this class were usually received after survey when the areas recorded by the survey were employed in the tax-receipts forms.

defined as equal to 333⅓ square qassabas. That the tax was at once reduced on the true area being ascertained occasioned little satisfaction to the owner for he could no longer obtain his rent on the larger area and so found himself worse off in this respect, which considerably more than counterbalanced the benefit he derived from the remission of tax.

The necessity of finishing registers before all the "gezira" lands were uncovered, caused other complaints as already explained, and many disputed the correctness of recording land in the name of the State, which was claimed by a private individual although he frequently could produce no documentary proof. Lists of Government property were furnished by the Department dealing with it and were followed as exactly as was possible; all complaints were forwarded to this department for action, so that the surveyor had no responsibility or discretion in the matter.

The other class of Government land, viz., that which comprised the Public Domain ("munafa amumia") also presented certain difficulties since the area alone was given in the old registers, and there were seldom details enough to locate the different portions of land of which it was composed. Strictly, land is only constituted a part of the Public Domain in virtue of a decree to this effect,* but in the course of the survey many pieces of land, such as main canals, were met with on which tax was still being collected from the neighbouring landowners, although the area was, or should have been, part of the Public Domain. By the canal act of 1894 all canals which watered more than three villages were to be considered as of public utility; the Ministry of Finance therefore gave instructions that in such cases the canal area was to be shown as belonging to the Public Domain, and therefore as untaxed. This procedure was responsible for a part of the reduction of the tax-paying area, which resulted from the recent Cadastral survey.†

Execution of the Chain Survey.

At the beginning of 1897 a theodolite traverse everywhere furnished a basis for the chain survey, which measured and recorded the dimensions of the individual plots. Work was now being definitely organized

* See Article 9 of the Civil Code.

† See tables at the end of Chapter XI.

to furnish the area of each piece of land possessed by each landowner so that the tax upon it might be re-assessed.

The surveying or technical branch still prepared only the map-sheets and the index to them in the form of a land-register; the plots belonging to each proprietor were collected together by the Settlement branch in order to obtain the total area possessed by each proprietor as an index to property. This involved taking the land-register and a tracing of the maps into the field again and dealing with the inhabitants for the second time, as well as investigating any complaints which might be made. This work did not advance very rapidly and in 1897 twenty-seven additional surveyors were transferred to the settlement branch in order to expedite that portion of the work.

There remained a hundred and fifty surveyors in the Technical branch, each of whom could, it was estimated, complete 3,000 feddans (1,260 hectares) annually, while the opinion was expressed in the report on the work for this year that this amount might be increased to 4,000 feddans (1,680 hectares) per annum.

At the end of October 1897, the provinces of Sharqia, Beheira and Gharbia were under survey. In Sharqia all but eight villages were finished, and these were to be finished by the end of the year, but they were not actually completed until the middle of 1898. Twenty-five villages of Beheira were in hand and were eventually finished early in 1899. Gharbia province had been begun, but 900,000 feddans (about 380,000 hectares) remained to be done; this amount including a large area of waste or marshy land in the northern part of the province, and a year and a half was estimated as the time necessary to complete the province with the whole of the staff then available, viz., fifty-one engineers, a hundred and forty-three surveyors, twenty-three draughtsmen and computers.

Traverse points were now being employed, but the number was wholly insufficient to furnish an effective control. Much of the land in the northern part of the provinces was waste and therefore the patches of cultivation occurred at intervals. In both Beheira and Sharqia provinces the greater part of the area had been surveyed by the elementary methods of triangulation with the plane-table which the State Lands Survey had employed and only the remaining portions were now being completed on the basis of a theodolite traverse, so that

it was often found to be impossible to make common boundaries agree accurately.

At the end of the year the staff consisted of :—

6 inspectors,
48 engineers,
167 surveyors,
30 draughtsmen, computers and clerks,
400 chainmen.

1898.

By this time the re-assessment of the land-tax had been virtually decided upon and it became necessary to increase the rate of out-turn if two provinces annually were to be ready for the re-assessment commissions. To do this efficiently a wider organization was needed and in July the present Survey Department was formed in which triangulation might be provided as the control of the traverse and chain-survey and where the drawing office and lithographic printing office could undertake the publication of the maps as they were completed.

In the first half of the year much progress was made in Gharbia province, and in the summer a commencement was made of the survey of Embaba district in Giza province.

In Gharbia the work was everywhere based on the points fixed by the theodolite traverse, but any which were lost or which had been removed were replaced by graphic triangulation with a plane-table. In most cases this method, if carefully employed, could reach the necessary accuracy, but no verification was possible since no angular measurements were booked which could afterwards be examined mathematically as a control. For this reason the use of the plane-table for locating points was abandoned as soon as the Survey Department was formed and a staff was available to re-traverse such lines as might be necessary. Work was mainly concentrated in the southern part of the province where the land is greatly subdivided and is of good quality. Here the holdings are fairly regular in shape, but as the more northern portions are reached they become much more irregular on the margin of the waste land since there the more favourable

patches are cultivated first and the intermediate areas are taken up as reclamation extends.

The staff employed in this year consisted of :—

6 inspectors,
48 engineers,
157 surveyors,
About 400 chainmen.

The total area which was mapped in this year on the scale of 1 : 4,000 was 948,000 feddans (400,000 hectares).

1899.

At the commencement of this year work was being carried on in eight districts of three provinces ; in Giza, the districts of Embaba, Giza, Ayat and Saff were all in hand ; in Gharbia those of Talkha and Sherbin, in the north-eastern portion of the province, were under measurement ; while Ashmum and Tala districts in Menufia province had been begun. In all these districts 363,265 feddans (152,500 hectares) were completed during the year. This was a very considerable reduction from that which had been completed in 1898 and the difference was due to a radical change which was made during the year in the procedure for compiling the registers. From this time onwards the Survey Department prepared not only the register which formed the index to the maps but also the other one which was an index of properties arranged in alphabetical order of proprietors. This latter register had since 1896 been prepared by the department of State Lands, but this division of the work was found to lead to a loss of time and was therefore abandoned. This change threw a largely increased amount of work on the staff of the Survey, since not only was the amount of records for each village doubled, but also there was a large number of villages (326) which had been surveyed under the old system, and which had been passed to the department of State Lands to complete and to settle, but which had not up to this date been finished. All these were returned for revision and completion. In Egypt, small plots of land are constantly changing hands and as yet no registration of such operations is obligatory ; consequently, the revision of a village-map and land-register when one or two years have elapsed since the time when it was surveyed necessitates alterations in a very large proportion of the entries, amounting almost to a re-survey.

The following table shows the area which was thus received from the department of State Lands in order that both maps and registers might be brought up to date, and also the years in which the villages had originally been surveyed :—

Year of survey.	Province.	No. of villages.	Area in feddans.	Total area in feddans.
1895	Beheira	3	27,809	126,744
1897	"	4	7,524	
1898	"	28	74,021	
1899	"	6	17,390	
1897	Sharqia	2	9,763	9,763
1898	Gharbia	205	497,569	651,746
1899	"	78	154,177	
	Total ...	326	788,253	788,253

To deal with the mass of revision, at first one and then a second inspectorate of the Survey had to be employed, for the work of re-assessing the land-tax in the provinces of Beheira and Sharqia was proceeding rapidly, and two more provinces were needed by the end of 1900. Fifty subordinate employees, register writers, were transferred from the department of Government Lands to assist but, being writers only, they did not greatly increase the rate of work.

By the end of 1899 the following amount of revision had been completed :—

Province.	Villages.	Area in feddans.
Beheira	43	116,909
Sharqia	2	9,783
Gharbia	71	241,120
Total...	116	367,812

Up to the end of December 1899, the survey of villages in the provinces which had been commenced stood as follows :—

Province.	Not commenced.	Awaiting revision.	Under survey.	Completed.	Total.
Beheira... ...	—	—	8	308	316
Sharqia ...	—	—	2	387	389
Gharbia... ...	25	193	102	189	509
Menufia... ...	37	—	129	—	166
Giza	59	—	78	—	137

The total area surveyed up to the end of this year was about 2,589,000 feddans (1,087,000 hectares), leaving 4,817,500 feddans (2,023,751 hectares) yet to be measured and mapped.

Work was becoming more organized, and the average number of days occupied in surveying a given area had decreased from what had been required, till now only 3·64 days were needed on the average to map 100 feddans (42 hectares) and 8·15 days to prepare the corresponding land-registers.

It was at this stage of the work that the scale 1 : 4,000 was found to be inconveniently small, for all holdings were being plotted, and also the work was being carried on in highly-cultivated and densely-populated country.

For the first time now the work lay in lands which were flooded annually, namely, in Giza province and here fortunately a network of triangulation was available though it was not of as high accuracy as was desirable. A very low Nile flood facilitated the survey of the basin lands, but rendered it necessary to postpone the measurement of certain villages in Saff district on the east bank of the Nile, since large areas of them could not be cultivated. The principal difficulties encountered in this province were, the existence of undefined boundaries both of property and of villages on the edge of the western desert; the use of a short qassaba of about 3·50 metres when the old lists of property had been compiled, which caused apparent deficits when the land was measured with the legal qassaba of 3·55 metres; and the large groves of date-palms in which not only was the land extremely subdivided but the land and the trees were often owned by different people and a certain area was considered as belonging to the owner of each tree.

1900.

In this year work was somewhat delayed by the fact of the Nile flood having been exceptionally low in the previous year. A part of Saff district in Giza province could not for this reason be cultivated till after the flood of 1900 and consequently its survey had to be postponed until the end of this year. Work was carried on in the Fua, and Sherbin districts of Gharbia, in all the districts of Giza and in Ashmun district of Menufia province. These were almost completed during the year except the six villages in Saff district. Triangulation in the Fayum province having been completed, the chain survey of it was taken in hand. In order to make up for the delay caused by the revision of the 788,000 feddans of land in the Delta an additional inspectorate was authorized in August 1900, but it was not completely formed and trained until the end of the year. The amount of work dealt with in the twelvemonth was as follows :—

Surveyed in the field and plotted, 449,540 feddans.
Land-registers compiled, 972,214 feddans.

The latter number includes about 546,000 feddans of land which had been revised, and for which new registers had to be prepared.

The rate of work both in the field and in the compilation of the registers improved, as is shown by a comparison with the number of days taken in the previous year per 100 feddans :—

Year.	Days per 100 feddans.		
	Field work.	Registers.	Total.
1899... ...	3·65	8·15	11·8
1900... ...	2·7	3·7	6·4

The northern part of Gharbia province was completed in this year after a good deal of trouble had been caused by village boundaries being wrongly pointed out. In the waste lands the boundaries extend for miles towards lake Borollos without any topographical features to define them and the canals and drains do not usually coincide with village limits. Traverse lines had been run along what were said to be

the boundaries but when the areas were computed for each village they were found to disagree with those hitherto in use and thus produced confusion in existing records. The Government, private companies and individuals all owned large blocks of land in this semi-cultivated region, which had been defined as consisting of a certain number of feddans on the basis of an utterly inadequate survey. What the Survey Department was able to do to improve matters in 1900 did not amount to very much, since the detail survey had been commenced in 1896 without any triangulation, and these questions cannot be wholly decided until the triangulation now (1908) in hand is finished and a new detail survey is made.

1901.

In this year work was confined mainly to the provinces of Menufia and Fayum, though a certain amount of work was done to complete the provinces which had been under survey in the previous year. A large area of waste land in Sherbin district which lies in the north-east of Gharbia province was completed during the summer, as this part of the country is too wet to be surveyed in the winter months.

In the Fayum the conditions were very different to those which had been met with in other provinces; the land is watered by the Bahr Yusef which enters the province on the south-east at the village of Lahun at an altitude of 26·5 metres above sea-level. On entering the Fayum depression, the Bahr Yusef is soon divided into a number of supply canals which carry the water to the fields; the surplus water is carried by drains to the lake, the Birket Qarun which lies at the north-western end of the depression situated 42 metres *below* sea-level, and is all that now remains of the ancient Lake Moeris, which at one time covered almost the whole of the province. In consequence of this great difference of level between the north-eastern and the north-western portions of the province, the water channels have everywhere a considerable slope and form meandering rivulets in every direction; holdings are therefore much more irregular in shape than elsewhere, and the work of surveying them was more difficult and tedious. The streams have also in many places eroded their beds until they lie below the level of the cultivated land, and are bordered with cultivated holdings on this lower level; all these peculiarities presented new difficulties to surveyors, who had hitherto experienced nothing but level alluvial lands. As has been

mentioned in a previous chapter (XIV), it was in the Fayum that traverse marks were removed to an exceptional extent, and the chain survey was repeatedly delayed by the necessity for replacing those which were missing.

1902.

The chain survey was still being carried on in the provinces of Fayum and Menufia on account of the various hindrances which had delayed the work, but these provinces were both to be re-assessed this year, so that it was only by the greatest exertions that the last villages were completed in time ; employees had to be divided into reliefs and work carried on for as much as 12 and 14 hours daily to complete the checking and fair-writing of the registers by the dates specified. By the end of the summer, however, the whole staff were working in the provinces of Daqahlia and Qaliubia where the work progressed much more favourably, since the triangulation and traverse marks had been more respected.

All work was carried on in this year in provinces which had perennial irrigation and their lands were therefore under crops during the greater part of the year. On the one hand this resulted in greater permanence of boundaries which facilitated the mapping but delay was caused by the cotton crop and the durra crop which when high prevented all surveying work. In the province of Qaliubia the feddan was usually less than the legal 24 qirats, being very frequently from 20 to 23 only, and in one village, Sindiun in Qaliub district, a feddan consisting of 16 qirats only was met with. In every case the land was now measured up in feddans of 24 qirats equalling 333⅓ square qassabas of the legal size, so that the area recorded to landowners was very generally reduced by a small amount. The reduction in the taxed area of this province amounted to about 5,650 feddans, but this includes a certain area of canals, etc., which had hitherto been taxed but were now recorded as a part of the Public Domain.

1903.

The survey of Qaliubia province was completed in this year by May, 91,000 feddans having been under survey at the beginning of the year. Daqahlia province was less advanced, 248,000 feddans being under survey in January but the remainder, amounting to 402,240

feddans were taken up and completed in the course of the year. After this it was necessary to transfer the staff to Upper Egypt in September, where the land had to be measured before that of middle Egypt which was in process of conversion from basin to perennial irrigation; by the end of the year all the villages in Qena province except twelve had been commenced.

Here the difficulties of surveying land which was annually inundated were again encountered as well as others of a different kind. The practice of considering up-stream and down-stream as equivalent to south and north where the direction of the river is not approximately meridional (see p. 24) caused great ambiguities when title-deeds and descriptions of property had to be compared with the land itself. The short time in each year during which the land was under cultivation and plots could be measured up, checked and complaints investigated necessitated work being carried on at very high pressure. No little difficulty too was met with in ascertaining whether some of the water-channels in the basins were State property or belonged to private individuals, since their margins were frequently ill-defined.

1904.

With the transfer of the work to Upper Egypt, the difficulty already referred to, that the cultivable lands are mostly submerged by the inundation from the middle of August, when the water begins to enter, until November, when it has drained off and the mud begins to dry, affected the work in every branch of the Survey.

After the flood the inhabitants re-mark their holdings and measure them out. The field-work of the Survey and the investigation of complaints had therefore to be carried out during the period December to July and in the remainder of the year only village sites, banks, and small unflooded areas could be taken in hand. The inundation also interfered with the work of the re-assessment commissions so that the latest date for completing the maps of any province by the Survey was advanced from February to the previous November; but as three months of the inundation preceded November this change meant that all investigation in the field had to be finished before the flood, or six months earlier than heretofore. The pressure of work was thereby greatly increased, and the cost of such accelerated work naturally rose.

At the commencement of the year the whole of the staff were working in the provinces of Aswan and Qena, both of which provinces were completed during the year, and a considerable area of Girga province (294,000 feddans) was also taken up. The out-turn of the year was less than that of 1903, but the special conditions which exist in Nubia and Upper Egypt fully account for this. The delay caused in the survey of basin lands by the annual flood has been alluded to; but the flooding of the basins and the deposition of silt from the impounded water also made it extremely difficult to find the iron marks placed by the traversers. In Upper Egypt they were very commonly removed for their value as iron, and therefore it was essential that they should be set low in the ground so as to be inconspicuous, which rendered them particularly difficult to find after the flood.

Above Aswan and from there to Wadi Halfa the Nile Valley is very narrow; no continuous belt of cultivation exists, but only isolated patches occur of greater or less extent and always of very narrow width, seldom exceeding two or three hundred metres. For long distances the sandstone cliffs and the drift-sand of the desert come down to the water's edge. The alluvial plain here is everywhere high and is never topped by the flood though the water of the Aswan reservoir now submerges it for about 60 or 70 kilometres during the first five months of the year.

"Land tenure in Nubia* differs from that of other parts of Egypt in that plots are usually owned and occupied by a number of individuals, and are recorded in the name of the bailiff (kholi) as "So-and-so (the kholi) and company". These plots vary in size up to about 25 feddans and are distinguished by the name of saqia.† A saqia will often consist of a long group of huts on the desert edge together with the cultivated land between them and the river. The saqia was presumed to be a plot of land which could conveniently be irrigated by one water-wheel, but now additional wheels are often added.

"In the district of Derr until comparatively recently large areas of land, often comprising whole villages, were claimed by the kashef,

* Communicated by Mr. G. H. Morgan.

† Water-wheel.

who constituted himself an authority who collected taxes and tribute from the villagers and administered justice. The kashef family is still represented in Mohd. Suleiman Kashef, who resides at El Diwan, and, although he no longer has any official status, he is still respected as a power by many, who continue to pay him voluntary tribute.

"During the detail survey in 1904 lands were found in the villages of Tomas wal Afia, Korosko, Abu Handal, Tinqala and El Riqa which were registered in the name of the kashef as owner and occupier, but upon enquiry it was stated that the kashef was only the nominal occupier who previously collected the taxes from cultivators and paid them to the Government, but that the present occupiers had inherited the lands from their ancestors for some time back and were now paying their taxes direct.

"An interesting question arises as to whom the lands actually belong. The Survey recorded the names of the permanent occupiers, but this decision was afterwards reversed by the mudiria upon appeal by the kashef."

1905.

The provinces of Girga and Assiut were now under survey, and an area of 499,000 feddans, having been already completed in the field in the previous year, had now to be recorded in land-registers.

The area to be completed during the year was roughly 800,000 feddans, and to accomplish this it was necessary to maintain the staff of most of the inspectorates above the average strength of thirty surveyors. In spite of the increased staff it was found necessary to increase the hours of work during the late summer and autumn in order that the records of Assiut province might be completed and sent in, and every inspectorate, without exception, had to resort to overtime work at night.

Not only was the amount of work to be done during the year exceptionally large, but there were also difficulties in Assiut province which had not been met with in previous years. The greatest of these was the excessive amount of transfers of land between villages ; in one district alone there were 24,000 cases requiring special investigation and checking, and in several other districts properties were nearly as much scattered, especially in those of Abnub, Abu Tig, and Badari. The boundaries of villages had sometimes to be altered in order to

avoid the occurrence of detached portions but it was often difficult to decide upon a new boundary which should be satisfactory to all concerned without a considerable loss of time. In many cases also, the lands of two or more villages were so much intermixed that it was impossible to survey them otherwise than as one village.

The area surveyed during the year amounted to a total of 868,600 feddans, which was an increase of 288,600 feddans on the out-turn of the previous year. This increase is due partly to the increased staff, but also to the high pressure at which work was carried on during the whole year.

The province of Girga was completed in July 1905, and that of Assiut in December.

The lands of Minia province were commenced in May, 1905, and by the end of the year 373,000 feddans had been completed in the field.

The province of Beni Suef was taken up in the autumn, and 220,000 feddans were completed by the end of the year.

Considerable delay was caused both in Minia and Beni Suef provinces by postponing the survey of the villages in which the lands of the Daira Sania Company were situated, until December, since the purchasers had not taken delivery of their land before and it was not possible to proceed with its measurement until they had done so.

No little difficulty was experienced in the basin lands of Upper Egypt and especially in those of Assiut province in the determination of field-boundaries; the villagers themselves could seldom locate their own lands, so that the annual measurements and demarcations were made for them by the village "dallal." With regard to the top and bottom limits of the plots there was seldom any question, but endless disputes arose over the side boundaries. The "dallal" used a book of measurements and records dating from the cadastre of Bahgat Pasha made in 1854–1859, and, with the qassaba rod measured off the widths of each man's strip; but, unfortunately, the totals of these as actually measured did not tally with the recorded total of the qibala or hod. Owners having deficits naturally protested, while those having excess maintained that the measurements were correct. A re-measurement would be made and a few centimetres deducted from each qassaba in order to adjust the totals by practically reconstituting by this means the length of qassaba used in the old survey.

These annual re-measurements also caused considerable delay to the Survey; for example, a qibala or hod would be demarcated by stones at the top and bottom of fields, the surveyor having been informed that these constituted definite boundaries, would complete his work; it would then happen that a dispute over areas would arise and the whole qibala would be re-measured by the dallal and the field boundaries altered. Check lines, when measured, frequently showed that the map as plotted was wrong, but from indications on the ground it was clear that the survey was right according to the limits as at first shown, but that the boundary stones had been moved while the surveyor was at work in another part of the village. It was difficult to get all the occupiers to be present at the time of survey, for the villagers in general had more confidence in the "dallal" than in the surveyor and did not trouble to ascertain whether the points taken by the latter represented their boundaries or not. This was particularly the case in the village of El Sahel in El Badari district, where all, from the "omda" downwards, admitted that the "dallal" was the only man in the village who knew where their lands were, and maintained, therefore, that it was unnecessary for them to be present. On one occasion the "dallal" fell sick and the survey had to be suspended till he recovered.

1906.

The cadastral survey of the country would have been completed in this year but the irrigation conversion works in Beni Suef province were not finished before the Nile flood commenced. Certain villages therefore had to be left until the river fell and their maps and registers were completed in the early part of 1907. By the end of June, 1907, the last village was sent in and the large-scale survey of the cultivable lands of Egypt was completed in nine years from the formation of the Survey Department in July 1898 and 16 years from the commencement of the State Lands Survey in 1892. The work had now advanced to a much higher standard than during the early years of its existence and the maps of Sharqia, Beheira and Gharbia left much to be desired when compared with those of Daqahlia, Qaliubia and of Upper Egypt. At the meeting of the General Assembly on April 12, 1905 the member for Sharqia province proposed that the Government should be requested to undertake a re-survey of the province. This was taken in hand

as soon as staff was available from Beni Suef, and was finished this year 1908. Beheira province is now in hand.

1907.

At the end of the year the strength of the cadastral staff was as follows :—

1 director,
7 inspectors,
58 engineers,
260 surveyors.

Cost of Work.

Much depends on the rate of salaries paid and in some countries insurances or contributions to pension funds are included. Also the triangulation which is utilized for the large scale land-survey is also used for topographical maps and other purposes. In this chapter the cost of field-work includes salaries of engineers,surveyors and chainmen, of computers and checking staff, and all expenses incurred until the maps have been inked in and the plot areas computed ; while that of compiling the registers includes the cost of all work done in collecting names of owners, writing up the registers, checking them, investigating objections and preparing fair copies.

It is difficult to give such an estimate of the cost of the chain-survey as can be compared with similar work in other countries. From 1892 to 1896 the cost of the field-work was not kept separate from that of compiling the registers. For 1896, the amount of each kind of work is given, but not the separate cost. In 1898 the Survey Department was formed and changes were introduced in the procedure. In 1899, the transfer of all the registers to the Survey Department necessitated the revision of some 800,000 feddans which had previously been surveyed and this greatly disorganized the regular work throughout 1899 and 1900, as already related.

It was only in 1901 that the conditions of work became normal, and the results of this and subsequent years can be compared, as in the following table :—

TIME AND COST OF CHAIN SURVEY OF 100 FEDDANS (42 HECTARES).

Year.	Days.	L.E.	Mill.
1901	5·4	1	428
1902	5·9	1	400
1903	5·0	1	155
1904	5·3	1	171
1905	3·7	0	854
1906	3·3	0	713
1907	6·6	1	630

In this cost is included the cost of the chain survey and the plotting and inking-in of the map; also the salary of the engineer who superintended the work, but not that of the inspector.

The cost of the work at first fell steadily as the organization improved, in spite of increasing salaries, but recently these have caused a rise in the figure, while the introduction of several improvements, which only became possible when the stringent conditions of time-limit came to an end, has tended in the same direction; of these the principal ones are the preparation of a special report on each plot owned by several persons in shares, and the computation of some areas by mensuration. The following table gives the average number of inspectors, engineers and surveyors employed in each of the eight years 1900–1907:—

	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
Inspectors...	7	8	9	9	9	10	9	10
Engineers	43	42	37	45	65	67	59	62
Surveyors...	212	227	247	222	240	246	249	278

CHAPTER XVII.

Land-Registers.

The land-register had from very early times, as we have seen, contained the record of each landowner's property together with a certain amount of additional information which varied with the special object for which the register was maintained, as well as with the care devoted to the work. The area, the nature, and the value of the land, the owner's name, the amount of tax due from it to the State, either in kind or in money, can be conveniently inscribed in a register, but its location can only be approximately defined. No guarantee is possible that one piece is not included in the property of two individuals, or that other portions have not been omitted altogether. This safeguard is furnished by maps alone, to which the land-register is complementary, being at the same time an index to the map and supplying much information that could not conveniently be inserted on the plan of a piece of land. The two therefore supplement each other and both are essential to a complete and efficient registration of landed property.

The indications furnished by a land-register may be regarded from two different points of view, viz., the fiscal and that of the landowner. In the first case the area and the value of the land is of the principal importance in order that the State may ascertain the amount of tax due from the land, and the person by whom it is to be paid; in the second case the landowner desires to know the location, the dimensions, the shape and the area of his land that he may preserve it from encroachment, as well as the rate of tax levied on it; these, when accurately recorded by competent authority, furnish a basis for the legal registration of his title to the land and of his right to hold it or to dispose of it to another.

As we have already seen in Chapter IV the land-registers of ancient Egyptian, Graeco-Roman and Arab times took count of the landowner's requirements as fully as the fiscal ones of the State; or, to state it more correctly, the same system was employed continuously, with but little change, as had grown up in early times when the first need was that of the landowner to measure and record his boundaries, while organized taxation by a central authority did not arise until later, and then use was made of the existing system of registration.

Occasional references in ancient papyri, on ostraca and in the papyri of Græco-Roman date from the Fayum, Bahnessa and elsewhere which have been already alluded to, and the Arabic cadastral registers are all in essentially the same form ; the dimensions of each plot are given, together with the area deduced from them, and also the name of the owner and the class of land. From this information, on the one hand the landowner knew the dimensions and the area of his land, and on the other the State could calculate the amount of tax due from it. Its faults lay in the inaccuracy of the measurements and the erroneous character of the computation of the areas. The control of the detailed measurements by others of a different kind and of higher precision with the object of preventing the accumulation of errors, which is the principal feature of modern land-measurement, was not practised in earlier times so far as is known. The special convenience of recording the dimensions of plots has already been discussed (see page 70) for, in the basin lands which were flooded annually by the Nile, holdings were measured up and marked out every autumn as soon as the water had drained off and the ground was sufficiently dry. In this process the lists of land which were kept in each village were indispensable, for they contained the breadth of each plot as measured along certain lines, and the length was also recorded at short intervals. With their aid, therefore, the holdings were, and still are, rapidly reconstituted each year, the annual repetition of an operation which dates from the highest antiquity.

The causes which led to the commencement of a cadastral survey in 1878 were essentially financial, and those too which determined the development of the State Lands Survey of 1892–1896 into a cadastral survey in 1897 were of a similar kind ; in each case the urgent necessity for an equitable re-assessment of the land-tax necessitated the execution of a land-survey in as short a time as possible, which would enable this financial reform to be carried out. To have recorded also the dimensions of each holding would have materially delayed the re-assessment, so that the fiscal aspect was given the greater weight, and though the holding of each landowner was accurately plotted on the maps, this was of less practical value to the small landowners than the older system which stated the dimensions, for it required more knowledge to measure them on a map with a scale than to take them from a written document and the result could not be so accurate.

Thus we find to-day in the villages of Upper Egypt that the plots in the basin lands are still laid out yearly with the aid of the land lists of 1854–1859, and not by reference to the new maps. On the other hand, in parts where perennial irrigation exists and field boundaries consequently remain visible throughout the year, the maps are used with more facility.

In 1880 the Cadastre commenced to prepare a land-register in a form which differed considerably from that previously in use, there being pages ruled with columns for different classes of information instead of the short description of each holding which had been the characteristic form of all previous lists for many centuries. The new form, which was actually an index to the maps, as well as the second register, the property-index which was introduced in 1883, were designed to furnish a complete account of all the cultivable lands. As has been already related in Chapter VII no province was ever completed, although the maps and registers of 654 villages were compiled and sent to the Ministry of Finance, so that no new tax-registers were compiled from them.

When the survey of State lands in Sharqia province was commenced in 1892 the existing registers were based on those prepared in the old way under Bahgat Pasha in 1854–1859, and which had been revised from time to time.

In 1896–1897, when the work was being systematized with a view to carrying out a general land-measurement, considerable alteration was made in the form of the register.

In the central office of each province the land-tax register of every village in it is kept and is known as the "mukallifa." In its present form it consists of a large book, 34 cm. by 44 cm., having each opening ruled into 27 columns which contain various information about the property of each landowner, and the amount of tax which in due from him.

A list of tax-payers and the amount due from each is taken from this register, and kept in the village by the tax collector to guide him in collecting the taxes due from each landowner.

The object of the cadastral survey of each village was to verify and correct this information. It was well known that clerical errors, miscopying, incorrect computation, and occasionally wilful falsification, had introduced numerous inaccuracies, so that entries could not be accepted as being probably accurate but had to be verified and brought up to date on the ground. This verified information was

then entered in a register of a somewhat different form from which a new "mukallifa" was afterwards compiled in the Mudiria.

The form of land-register (daftar el Messaha) used since 1897 is given below, where the columns in each opening are enumerated.

(TRANSLATION).

Province _____

District _____

Village _____

(Right-hand page)*

LAND

Name and Number of Hod.	No. of each plot.	Areas.						Category of Lands.	Old Name of Hod.	Tax.										Names of Owners and Occupiers.		
		Area of each plot.			Area of Classes in each plot.					Final Tax.				Temporary Tax.						In Mukallifa.		
										Area.			Rate.	Area.			Rate.			Names of Registered Owners.	Names of Occupiers.	Names of Present Occupiers.
		Feds.	Qir.	Sms.	Feds.	Qir.	Sms.			Feds.	Qir.	Sms.	L.E.	M.	Feds.	Qir.	Sms.	L.E.	M.			
(1)	(2)	(3)			(4)			(5)	(6)	(7)					(8)					(9)	(10)	(11)

(Left-hand page)*

REGISTER.

Kind of Occupation.	Distribution of Shared Plots.	Remarks.
(12)	(13)	(14)

* Since Arabic is written from right to left the pages are placed as above indicated but column No. 1 is on the right-hand side of the right-hand page.

Column No. 1 contains the number of the hod commencing with the first hod and when all its plots have been recorded the second hod is similarly entered, and so on throughout the whole village.

Before 1899 there were the old hods which had been long in existence; after this date new and smaller hods were made by the surveyors with the aid of the village authorities. In the provinces of Sharqia, Beheira and part of Gharbia which had large hods, the subdivision of them was carried out by the re-assessment commissions in the course of their work. The names and numbers recorded on the cadastral maps were maintained, but the subdivisions which were found to be necessary were described as Qism 1, Qism 2, etc.

Column No. 2 contains the number of the plot; these numbers are given so as to run as nearly as possible consecutively in the hod, so that, for instance, on the map plot No. 5 usually lay between plots Nos. 4 and 6 if possible, and in any case was close to them. It was never laid down very precisely what was to constitute a separate plot. In the State lands survey this was not important since Government property and private properties of more than thirty feddans alone were mapped, smaller holdings being measured up and recorded only. If they were very small it was the usual practice to include several to form a single large plot. When the cadastral survey was begun each separately-owned portion of land was supposed to be shown, but the rule was not rigidly adhered to until 1899 when the present Survey Department had been formed. The scale of the map was then increased to 1 : 2,500, in order that the smallest holdings might be plotted. The average size of a plot is about two feddans but about forty per cent. of them are under half a feddan (0·21 hectare) and the smallest plot that is commonly met with is about 4 sahms ($\frac{1}{144}$ of a feddan = 29·17 square metres).

Column No. 3 contains the area of the plot in feddans, qirats and sahms, the result of two graphical measurements which are made as described in Chapter XV, and checked by comparison with the computed area of the sheet and of the village.

Column No. 4 gives the area of each class of land in a plot where there was more than one.

Column No. 5 contains the indications "kharagi" and "ushuri" which were used during the survey to indicate to which of the two classes of land (see p. 60) the plot belonged. As soon as the re-assessment of the land-tax had been completed and the new rates had come into force this distinction disappeared, and this column became unnecessary.

Column No. 6 contains the name of the old hod in which the plot lay before the new division of hods was made; this information was not always obtainable.

Columns Nos. 7 and 8 contain the permanent and temporary rates of land-tax respectively. In each case the rate of tax and the area which carried this rate are inscribed.

In the next three columns the owner of the plot is recorded. He might be either registered as the owner in the registry of the Courts or be the owner by purchase or inheritance without having registered his title. Until November 1899 both the registered owner (sahib el taklif) and the present occupier * (wadaa el yad) were recorded. There was no little difficulty in doing this, for the owner whose name was registered was often dead and the present occupiers were his heirs, or others who had purchased from him or his descendants. The old register gave the name of such registered owners, but it was often extremely difficult in the absence of definite boundaries to locate on the ground the property that they had formerly owned and which probably had since been much divided. The registered owner is now only recorded in cases of mortgage.

Columns Nos. 9 and 10 give information about the registered owner and unregistered occupier as they were recorded in the "mukallifa" at the Mudiria. The names were frequently no longer correct, because the land had very often changed hands by inheritance, by sale, by exchange, or in some other manner since the original entry was made.

Column No. 11 therefore contains the name of the permanent occupier as found at the time of survey but it was necessary for him to be in permanent occupation and not merely a tenant. The

* He had to be in permanent occupation and not merely a tenant.

character of his ownership, whether by purchase or otherwise is recorded in column No 12.

Since plots are so frequently owned in share by two or more proprietors who have not made any definite division of the land, but possess a certain fraction of the area, it is necessary to furnish details of such conjoint possession which are given in column No. 13, where the names of the partners, the proportional share claimed by each, and the area consequently due to each of them are all inscribed.

The remainder of the form is taken up by a wide column of remarks in which all additional explanations were inserted. These included mention of any law-suit or dispute concerning the plot, mortgages, note of wrong entry in old register, explanation of the plot being transferred from the register of another village, any special information, and the initials of the inspector if any alteration had been made in the entry. In this case the nature of the alteration was specified.

This land-register (daftar el messaha) was therefore an index to the map, the entries being arranged first in order of hods and then in order of plots in each hod. It contained the rates of tax, the names of past and present owners, and the shares held by partners in a plot. When completed, the areas of plots were totalled to give the area of each hod, and from these the total area of the lands of the village was obtained. This total was also divided so as to show:—

The area of tax-paying land;
The area of untaxed land, which was subdivided into:—
- the area occupied by the village buildings;
- the area of the State lands;
- the area of the Public Domain.

The second land-register (mizzania) contained the same information, but differently arranged in order to show the land which belonged to each landowner, the different rates of tax due from each portion, and thus the total area of his property in the village and the total tax due from him to the State. This register was of the same size as the land-register, and when finished was bound up with it.

(TRANSLATION).

Province _____
District _____
Village _____

MIZZANIA.

Number of Property	Name and Number of Hod.	Number of each plot.	Names of Occupiers.		Area.														
			Actual.	Registered in Mukallifa.				Kharagi.			Ushuri.			Public Utility.			Government Lands.		
					Feds.	Qir.	Sms.	Feds.	Qir.	Sms.	Feds.	Qir.	Sms.	Feds.	Qir.	Sms.	Feds.	Qir.	Sms.

(INDEX OF PROPERTIES).

Taxes.										Area owned by each name in every hod.			Difference.		Remarks.
Temporary.					Final.								Excess.	Deficiency.	
Feds.	Qir.	Sms.	L.E.	M.	Feds.	Qir.	Sms.	L.E.	M.	Feds.	Qir.	Sms.			

The old land-registers were everywhere very incorrect, since not only had inaccurate measurements, errors of copying and other mistakes crept in gradually, but property was constantly changing hands by inheritance, gift or purchase, without the transfer being regularly registered. The primary object of the survey was to obtain a record of the actual ownerhsip at the time of survey, and also to locate each property with reference to the neighbouring ones. It had to be admitted that the existing record was often incorrect and other evidence of ownership had therefore to be accepted. The Survey had no legal authority to decide in cases of dispute, nor did the act of recording any one as the permanent occupier give him any title to the piece of land. Such a record only amounted to a statement that on the date of the survey he was found to be in occupation of the land and not only a tenant of it; moreover, that in paying tax for it or possessing a title-deed or some other document to show how he had acquired it, he had produced some evidence of the permanent nature of his occupation. Whether he had a better right to the land than anyone else, or whether he had obtained it fraudulently was not investigated, since the survey was for fiscal purposes and had no judicial powers; the land had to provide the annual tax which was to be paid to the State, and the permanent occupier was responsible for paying it. If it was not paid, the State could seize so much of the land as was necessary to pay the taxes due from it. The kinds of evidence which were utilized for ascertaining the permanent occupier in doubtful cases were:—

(1) The old land-tax register (mukallifa);
(2) The occupation of the land at the time of survey;
(3) The possession of title-deeds whether registered or not;
(4) Statements of the sheikhs or the "dallal";
(5) Statements of the neighbouring owners.

The first of these, the "mukallifa," was far from reliable when the survey of a province was undertaken for the first time, but in the case of those provinces in which the maps are now being revised, having been originally surveyed by the State Lands Survey between 1892 and 1896, it has much greater weight. Here the mistakes of the older registers were remedied at the time of the earlier survey, and taxes have now been collected for twelve to fifteen years on the basis of the

statements recorded in the land-register which was then prepared, so that the onus of proving inaccuracies in it now rests mainly on the proprietor. It would not, however, be correct to say that no new errors have crept in during this period; on the contrary, the recent re-measurement of the province of Sharqia involved a minute checking of the registers with the holdings on the ground, and a good many clerical errors were found to have occurred. Plots on transfer have been recorded as being in a wrong "hod"; areas have been incorrectly entered etc.; so that there were a considerable number of such mistakes to be remedied.

A statement of the plots in the registers of Sharqia province which were found on re-survey to have been misplaced between 1896 and 1908 is given below:—

Name of District.	Total No. of plots.	No. of plots misplaced.	No. of villages concerned.
Belbeis	36,159	496	60
Faqus	37,598	2,500	45
Hehia	21,923	1,842	52
Kafr Saqr	31,340	2,201	53
Mina el Qamh	35,659	2,810	85
Zagazig	39,501	4,791	68
Totals... ...	202,200	14,640	363

Since the permanent occupier is being recorded, the evidence of being in actual possession of and cultivating a plot of land should be a good guide to the surveyor; but here also some precautions are necessary. He must not be merely a tenant, renting the land from the real owner, though it is a common practice of proprietors who own some land and rent more, to indicate a portion of the rented land as their own in order that they may be recorded in their name. It is also very common for a proprietor to own plots of land which are widely separated from one another and situated in distant parts of the village. He then not infrequently arranges with another owner whose land is similarly distributed that they shall effect a temporary exchange of plots so that *A* will cultivate one or more belonging to *B* but which are near to *A*'s hand, while *B* cultivates other plots of *A*'s which lie near to him. This arrangement may be renewed for years

without the plots ever definitely changing hands, and if care is not exercised they may be recorded as being the property of the wrong owner.

The possession of title-deeds should be conclusive evidence, but in many cases they tend to confuse rather than to simplify the matter. If they are unregistered it is difficult to verify their date and not infrequently they have been fabricated in order that they may be produced before the survey officials; if registered, the description of the property and of its boundaries is usually so vague and indefinite that it is almost impossible to locate them on the ground. The single fact that directions are only described as north, south, east and west renders them most difficult to use. A frequent complaint of landowners was that the Survey did not follow the indications of the old title-deeds produced to the exclusion of all other evidence; but in the first place such title-deeds were usually very ambiguous and could be interpreted in more than one way, thus overlapping the lands of one neighbour by one interpretation and of another if a different one were followed; again the lands described in the title-deeds may have been partly sold or otherwise disposed of; they may have been encroached upon by others who have been long left undisturbed thus giving rise to conflicting interests between which the officers of the Survey had no authority to decide. It was therefore left to the owner to indicate his boundaries and, if the land was not at the time being cultivated or otherwise effectively occupied by him, to show evidence of ownership. In cases where a dispute arose over a boundary and neither side were prepared to give way or come to an arrangement the two areas in dispute were included in a single plot pending a decision being given by the courts of law.

In cases where owners did not attend and did not send a representative, the only means of completing the survey of the village within the specified time was to follow the indications given by the sheikhs of the village and by the "dallal" as to the boundaries of the lands of absentee landowners. It is certain that cases of hardship occurred which it was impossible to prevent, as for instance where a large proprietor had for years rented a plot which the owner was too poor to cultivate, and had then indicated it to the Survey as his own property. Usually no written agreement of the lease existed, and the re-measurement of the larger proprietor's lands had usually resulted in a deficit which more than concealed such encroachments.

When these land-registers, each consisting of the two parts, the Index to the map (Daftar el messaha) and the Property index (El-mizzania), were completed, they were forwarded through the Ministry of Finance to the Mudiria office together with a copy of the map on which the village boundary was coloured red for convenience of reference. From these registers a new land-tax register (mukallifa) was prepared and taken into use; from it all tax receipts (wird) were made out so that errors in areas which were found during the measurement of the land were rectified at the next collection of taxes. When a considerable portion of the province had been completed the Re-assessment Commission commenced its work and assessed the tax which should be paid by the land in each "hod"; these new rates were not brought into force until five years after the re-assessment had been completed.

Unfortunately it has not been possible to keep these registers up to date by correcting the entries as changes took place. The local staffs of surveyors attached to the Mudiria offices were only accustomed to make measurements in the old fashion and to record them as had been done in the earlier cadastral surveys, but they had no experience of maps and were unaccustomed to the use of them; again, registration of transfers was not compulsory and was therefore often evaded to avoid paying the fees; and lastly such deeds as were registered at the registries of the International Tribunals had undergone no verification as to the dimensions and areas recorded in them, so that this information might easily be incorrect. When one party sold a piece of land to another, a deed of sale was drawn up describing the boundaries of the land, its dimensions and the area, for which a certain sum of money was to be paid. The two parties to the transaction were satisfied to complete the sale for the price named and accepted the area as being correct having agreed upon the plot which was to be sold. The Registrar registered the deed, but required no proof that the area and dimensions were accurate nor that the boundaries really defined the plot of land. The deed was then sent to the Mudiria office with instructions to record the sale and return the document within ten days. The area stated in the deed was therefore transferred from the total of the seller's land to the buyer's and if the area was incorrect both statements became incorrect also. With a constant supply of such deeds being sent down for registration containing areas which

had not been verified and which in many cases were inexact to some extent, it was inevitable that the land-registers which had been prepared by means of carefully checked measurements should become year by year less correct.

At first (1897) a mutation register was kept for each village to record such changes and transfers, but no greater accuracy was gained thereby, since the fault lay in the original statement of area being guaranteed by no responsible person and being liable to no check or verification. The use of these mutation registers was therefore discontinued after a few years.

The cost of compiling the registers, in which the computation of the areas of plots is included, depends partly on organization, but also on local conditions, among which the size of the holdings, the number of transfers fr m village to village, and the correctness of the information furnished in the village and the readiness of the villagers to assist are among the chief. The average cost per 100 feddans, both of field-work and the compilation of registers in different years is as follows for each of the last seven years; before that the procedure had not been fully developed and the work done in different years is not directly comparable.

Time and Cost per 100 feddans (42 hectares).

Year.	Field-work.	Registers.	Field-work.		Registers.		Total.	
	DAYS.	DAYS.	L.E.	MILL.	L.E.	MILL.	L.E.	MILL.
1901... ...	5·4	5·5	1	428	1	154	2	582
1902... ...	5·9	5·0	1	400	0	700	2	100
1903... ...	5·0	3·8	1	155	0	553	1	708
1904... ...	5·3	4·3	1	171	0	727	1	898
1905... ...	3·7	5·1	0	854	0	941	1	795
1906... ...	3·3	3·7	0	713	0	854	1	567
1907... ...	6·6	4·1	1	630	1	039	2	669

In 1907 the pay of employees was considerably raised and several additional checks to avoid errors were introduced which made the rate of work slower and consequently increased the cost. A very important modification was to make a special inquiry into every plot which was

owned by two or more partners. Experience gained in 1905 and 1906 in investigating the complaints against the survey in Girga, Assiut, and Minia provinces had shown that nearly eighty per cent. of the complaints arose from mistakes in recording such plots, due either to incorrect or wilfully false statements which were furnished. Written statements signed by the claimants were therefore prepared in each case, which greatly increased the work at this stage, but promises to diminish proportionately the number of subsequent investigations which will be necessary. This affected the cost of both the field work and the compilation of registers.

Thus it will be seen that the cost of compiling the registers at first fell and then varied slightly from year to year, rising as time went on with the increase of the rates of pay of the staff and the introduction of additional checks to prevent the recurrence of the classes of errors which were found to occur most frequently.

The general procedure of a surveyor in compiling the land-register of a village is as follows :—

1. The copy of the old register is returned to the tax-collector to be brought up to date by the addition of any recent changes of which the Mudiria office has notified him.

2. With the aid of the map he notes the name of the occupier of each plot.

3. He prepares an index of the landowners' names in the old register and adds any new names which he meets with in the work.

4. He writes out the Index to the map (daftar el messaha), hod by hod, from No. 1 onwards, and the plots in each hod in their serial order, entering the area of each.

5. He writes out the Index of property, which is arranged by the alphabetical order of the landowners' names, and collects under each name all the plots of which he is recorded as being in permanent occupation.

6. He totals the areas in these two registers to see that they balance correctly.

7. He prepares notices for each landowner setting forth the result of the survey of the lands recorded in his name.

CHAPTER XVIII.

The Reproduction, Storage and Distribution of Cadastral Maps.

The large-scale maps produced by the Cadastre of 1878–1888 were never printed, but tracings were made as required on tracing-cloth from the original sheets which were kept at the offices of the Cadastre. Maps of certain districts were reduced to the scale of 1 : 40,000 and were lithographed, but these were topographical maps prepared from the cadastral map-sheets for administrative purposes, and therefore need not be further considered here. A specimen is shown in plan XVII.

From 1892 the maps of villages were kept at the office of the Survey and two copies were prepared on tracing-cloth, one of which was sent with the land-register to the Mudiria, while the other was retained by the department of Government Lands, which had charge of the work so long as it was a State Lands Survey Each village was surveyed separately and a separate map was prepared of its lands, nothing being shown outside its boundary except the names of the neighbouring villages. Such tracings are not very satisfactory reproductions of original maps, for the tracing-cloth varies greatly in size according to the humidity of the air, additions or alterations are not difficult to make, and every tracing needs to be carefully compared with the original to eliminate errors of copying. The preparation of two copies of every map took up a considerable time, and the provision of copies for private individuals was almost impossible, while the cost was more than many wished to pay. The formation of the Survey Department in 1898 brought the Drawing and Lithographic offices of the Public Works Ministry and the Land Survey under the same direction, so that it became possible to reproduce maps of the village lands by lithography. When this was first done, in January 1899, the provinces of Beheira and Sharqia were almost completed and a large portion of Gharbia province had been sent to the Ministry of Finance, so that it was preferable to commence the regular printing of cadastral map-sheets with Giza province which was then being surveyed. No second order

triangulation, which had been connected to the "Transit of Venus" station on Gebel Moqattam yet existed, so that it was only possible to print the lands of each village as a separate group of sheets each one of which was fifty centimetres square. During the year much progress was made and when the chain-survey of the Fayum province was commenced it was controlled by a major and a minor triangulation, and the co-ordinates of all points were referred to an origin in the province of which the latitude and longitude had been determined by observation, for no reliable triangulation had as yet connected the Fayum network with the fundamental point on Gebel Moqattam. There was not, moreover, time to prepare all the tables needed for projecting the field-maps as sheets of a map on the "Gauss conformal" projection which had been decided upon. The Fayum cadastral map-sheets are, therefore, square sheets of fifty-centimetre side (see Chapter XV).

So, although it was originally intended to publish a complete series of map-sheets all of which should be full of detail instead of forming a separate group of sheets for the lands of each village, this was not possible until the provinces of Qaliubia and Daqahlia were undertaken. The employment of the system of full sheets with common sheet lines causes a little delay since a sheet cannot be published until all the villages of which the lands fall within the sheet are ready, though it leads to a great economy in printing. The provision of an adequate network of triangulation had already caused some delay to the chain-survey, and as the date for the re-assessment of the Fayum was not far off, it was necessary to push on the work and to publish separate groups of map-sheets for each village in it so as to be able to supply the re-assessment commissions with the maps of each village as soon as its land-registers were completed. By the time, however, that the provinces of Qaliubia and Daqahlia were being surveyed, it was possible to arrange that all sheets should be projected on the system adopted so as to form part of the regular series of map-sheets of the country. Menufia province, which was surveyed at the same time as those of Giza and the Fayum, had its map-sheets prepared in groups by villages, since there was no triangulation in this province by which the points could be accurately placed on projected sheets.

The survey was now transferred to Upper Egypt in order to leave the lands of Middle Egypt, which were being converted to perennial

irrigation, as late as possible before preparing their land-registers. This involved projecting all sheets with reference to a new origin, as has been already explained (see p. 132), and the sheet lines are consequently very slightly out of position in latitude and longitude. This only changes the geographical position of the sheet, and in no way affects the land-measurements. In Aswan province, where the valley is very narrow, the amount of triangulation and theodolite traverse work which had to be done was very large in proportion to the cultivable area, so that some delay was feared in completing the survey of this part. It was therefore taken in hand as early as possible at a time when the second order triangulation was not yet complete from Luxor to Aswan. The sheets of the Nubian portion of the valley had therefore to be projected on the basis of the longitude and latitude of a point on the Addendan base which had been obtained by astronomical observations made when the base was being measured.* These gave values which differed from those which the completed triangulation furnished later, but here again no error was introduced into the land-measurement, though the exact geographical position of the map-sheets was uncertain until the main valley triangulation was complete. After this, all sheets were of the normal series and joined correctly the one to another throughout Upper and Middle Egypt until the northern boundary of Beni Suef was reached. Here no actual junction with the lands of Giza province could be made on the cadastral maps, since those of Giza were on the scale of 1 : 4,000, while those of Beni Suef and the southern provinces were on the larger scale of 1 : 2,500.

The field map-sheets are issued to the surveyor with the traverse points plotted on them, and with the aid of these he carries out the chain-survey of the area and plots his measurements on the map-sheets. Thus canals, roads, paths, holdings, village and "hod" boundaries, the village site, and all other details are drawn accurately on the map. There was little time to be spared for training the surveyors to become skilled draughtsmen as well as capable chain-surveyors, so that colours were used to reduce the amount of "ornament," which needed a somewhat skilful draughtsman to render neatly. These colour symbols had to be translated into black by the draughtsman, who prepared the autographic copy for reproducing the map-

* See page 186.

sheet by zincography. A set of the field and lithographic conventional signs is shown on Plan XXV.

From the first the cadastral map-sheets were reproduced in this manner by autography and printed from zinc.

The field-sheet is first examined in the Cadastral office to see that all necessary information has been included, that there are no omissions, and that the correct symbols have been used; it is then passed to the Reproduction office for printing and publishing. Here the map is traced with lithographic ink on a thin sheet of transfer paper which is stretched over it, the draughtsman translating, as he works, the coloured symbols into their black equivalents; the numbers of the plots are more neatly written; the writing (Arabic) is done in the regulation style so as to reproduce clearly without being so large as to encumber the detail; and the finished tracing is carefully compared with the original before being sent to the printing office. Here it is laid face downwards on a sheet of grained zinc, damped, and the ink transferred to the zinc sheet by passing it several times under the roller of the proving-press. These presses are driven by an electric motor and a pressman can transfer on the average 16 sheets per day of seven hours.

The zinc sheets are then rolled up with printing ink and proofs pulled, to check with the original field-sheets. Any corrections which may be found to be necessary are easily made on the zinc plates, which are afterwards passed for printing.

The numbering of the cadastral map-sheets is based on that of the topographical map-sheets on the scale of 1: 10,000. The whole country is divided into quadrants by the intersection of the 30th parallel with the 31st meridian east of Greenwich, and each quadrant is divided into rows and columns by the lines bounding the map-sheets of the 1: 10,000 series; 3-7-N.E., therefore, will describe a sheet in the third row and the seventh column of the north-east quadrant. Each sheet of the 1: 10,000 maps contains sixteen cadastral map-sheets on the scale of 1: 2,500, and these are numbered in four rows 1-4, 5-8, 9-12, and 13-16, from north to south, so that sheet 3-7-13 would indicate the cadastral sheet containing land which fell in the south-eastern corner of the 1:10,000 sheet 3-7-N.E. The number of the cadastral sheet is printed on the right-hand top corner of the margin, and those of the neighbouring sheets are printed in the centre of the margins (see Plan

XXVIII). The name of the province, the district, and of the villages whose lands occur on the sheet are printed on the top margin, while the bottom contains the imprint.

In this imprint at the foot of the map are printed the date of survey, the principal conventional signs for boundaries, diagonal scales of metres and qassabas, and also a scale of areas. Those who are not in the habit of using maps frequently have no little difficulty in knowing whether a plot contains approximately three or four feddans, so in the imprint of all these maps are included squares representing to scale a feddan, a qirat, and a sahm (see Plan XXIX), while a square of 10 feddans is printed on all sheets of the 1 : 10,000 series.

To facilitate the calculation of areas each map-sheet will in future have the true area of the land which is included within its sheet-lines stated in the imprint.

Within the sheet, the land is divided up into taxation divisions ("hods") which are indicated by black triangular dots placed along the boundary lines. Within these, the plots are delimited by fine lines, even though they are bounded by no hedge or other topographical features. The great majority of plots have no recognizable boundaries, and such stones as exist are so rough and so insecurely placed as to be unreliable. Since continuous lines are reserved for property boundaries, roads, water channels, etc., which are not public property and therefore enter into the private holdings, have to be indicated by using dotted lines for their boundaries. This is not satisfactory, as a number of parallel dotted lines is highly confusing, but this procedure, which had been commenced in 1896, was maintained until the Re-assessment Commissions had finished their work. Now a clearer means of showing such features might be introduced with advantage. The plots are numbered as far as possible consecutively throughout each hod, each number being written on the map. At present, this number remains unchanged on the sale of a plot to a new owner. On the margins of the sheet the boundary lines of plots are carried over the sheet-line in order to facilitate joining sets of sheets together. Small plots, which contain a house and garden, were often hatched over to show that they were occupied by a building, without showing which part of the plot is occupied by the house and which by the garden but these features are now shown separately. Until quite recently, pressure of work has prevented the interior detail of the

village itself being shown; the area was untaxed and, therefore, was regarded as being of minor importance. The streets, alleys, open spaces, etc., are, however, of importance both for the administrative authorities and those responsible for the public health, so that this additional information is required and is now being recorded.

Such ill-defined boundaries as those of most of the properties in Egypt may seem difficult to identify on the ground by means of a map, but since the whole area is in an open alluvial plain, perfectly level and without any woods or copses, there is but little to interrupt a direct view; the different plots are laid out on the ground as plainly as they appear on the map, and in practice there is no difficulty in locating them by selecting any recognizable point in their neighbourhood. In provinces where perennial irrigation is in use, the numerous small water channels serve this purpose, since on land which is continually under cultivation they change their position but little. In basin lands which are flooded annually it is less easy, but here they are divided up by certain long lines which have been used for ages in marking out the plots, and these furnish useful guides; besides, the water-wheels and wells which occur not infrequently may also be utilized. The relief of the country is so slight that no attempt is made to indicate it except by hatching the slopes of the banks of large canals. Mounds which are the ruins of ancient towns are indicated in plan only, and the height of them is not shown. These are rapidly being dug away for the little nitrate that they contain, and the land on which they stand is being brought under cultivation.

Since these cadastral maps were first printed in 1899, the number in an edition has steadily increased; at first, 30 copies only were printed, but now 100 of each are required, except in the case of waste lands. Formerly 12 copies were sent to the Revenue Department and the Government Lands Department only, while a few were kept to meet the demands of the public. Since then the demand for them has steadily increased both on the part of Government Administrations and also of the public; the issues at the present time include—

6 copies to Revenue Department;
1 copy „ State Lands Department;
2 copies „ Khedivial Library;
10 „ „ Irrigation Circle concerned;

while additional copies are frequently demanded.

During the twelve months of the present year 1908, 82,008 cadastral map-sheets have been issued to Government Administrations, and 17,685 have been purchased by the public.

The sale to the public varies considerably for different sheets, but on the whole it reaches a total of about 14,000 to 18,000 sheets per annum. There is no doubt that this could be greatly increased if these maps were readily obtainable in the country districts. But this is not easy to arrange at the present time, for the Mudiria offices are the only ones where these maps could be dealt with, as reference to the land-registers would be constantly necessary. Then the work of maintaining a stock of the two to three thousand maps which include the lands of a province, and handling the same so as to effect sales regularly, is a work of considerable magnitude and requires an employee who is thoroughly conversant with them. This will naturally be a part of the work of local survey offices whenever they are established, but at present the work seems to be more than the Mudiria staff can do without assistance. Most landowners require not only the map of their lands, but also an extract from the land-register, and this was furnished by the Mudiria on the payment of a minimum fee of L.E. 0·430, which was a considerable sum for a small proprietor; later, in June 1907 the fee was reduced to L.E. 0·230, and since October 1907, the numbers of the hods and of plots which comprise a proprietor's land are given on payment of L.E. 0·030 only. The price of a cadastral map-sheet has always been 50 milliemes unmounted or 65 milliemes if mounted on cloth.

At the present time all the provinces have had their cadastral maps printed and published except Beheira, which is now being revised and will be printed on the scale of 1 : 2,500 in 1909. After this the maps of Gharbia, Giza and a part of Menufia will, when they have been revised, be published on the larger scale of 1 : 2,500, so that the total number of map-sheets for the Valley and Delta of Egypt on this scale will be about 30,000. The following table shows the number of maps for each province, and the year in which they were published :—

STATEMENT OF CADASTRAL MAPS PRINTED, FROM 1899 TO 1907 INCLUSIVE.

Mudiria.	Scale.	1899	1900	1901	1902	1903	1904	1905	1906	1907	Total Maps for Mudiria.
Gharbia ...	1 : 4,000	198	106	448	632	1,887	1	—	—	—	3,275
Giza	..	1	490	275	—	—	—	—	—	—	766
Menufia	..	—	222	270	—	—	—	—	—		492
	1 : 2,500	—	—	223	1,458	—	—	—		—	1,681
Fayum ...	..	—	—	102	2,161	—	—	—	—	—	2,263
Qaliubia ...	..	—	—	—	47	731	—	—	—	—	778
Daqahlia ...	..	—	—	—	28	1,669	540	—		—	2,237
Qena	..	—	—	—	—	—	1,575	—	—	—	1,575
Aswan ...	..	—	—	—	—	—	401	675	—	—	1,076
Girga... ...	..	—	—	—	—	—	—	1,313	—	—	1,313
Assiut ...	..	—	—	—	—	—	—	767	939	—	1,706
Minia ...	..	—	—	—	—	—	—	—	1,632	3	1,635
Beni Suef...	..	—	—	—	—	—	—	—	349	593	942
Sharqia * ...	..	—	—	—	—	—	—	—	—	571	571
	Totals...	199	818	1,318	4,326	4,287	2,520	2,755	2,920	1,167	20,310

The sale of these maps is attended by considerable practical difficulties on account of the lack of local agencies, and, small editions being necessary on the ground of economy, the reprinting of such maps as are sold out from a total of over 20,000 maps is yearly becoming heavier ; in 1907, 6,125 maps were reprinted for this reason.

The following is a statement of copies of the cadastral maps reprinted during the last four years :—

	Scale.	1904.	1905.	1906.	1907.
Cadastral Maps	1 : 4,000 and 1 : 2,500	1,200	716	4,263	6,125

* The total number of sheets in Sharqia will be about 2,840 of which 2,300 were printed in 1908. Beheira province will require 3,200 sheets on the scale of 1 : 2,500.

In a country where a very large proportion of the population is illiterate and where no shops exist which are capable of handling large numbers of maps, it is very difficult to bring cadastral maps within the reach of the small land owner until there is a compulsory form of registration that necessitates their use in all transfers of land. The proprietor requires to know the number of the "hod" and of the plots which correspond to his land, for he can seldom recognize them with certainty on the map, and therefore reference to the land-registers which are kept at the Mudiria office is necessary. The fee charged for extracts from these registers has been recently much reduced, but still the facilities for ascertaining which map-sheet is wanted are not great, for the tax-list in the village does not give the information though this would be of great assistance. Local Survey offices have not yet been established throughout the provinces, but these when they exist will be the natural means of distributing the maps. In the meantime various temporary expedients have been adopted; the engineers of the Survey accept orders for maps during the survey of a village and the maps are sent as soon as they are printed; whenever a revision or investigation takes place the employee who carries it out is furnished with copies of the maps of the village in order to meet any demands; but these measures are but palliatives, and at present not nearly as many small land owners possess maps of their property as would do so if they could be made more easily accessible.

The main stock of the maps is kept at the Survey Department Offices at Cairo, where they are stacked on tiers of steel shelving, the top sheet being turned upside down to keep them clean. Though there is much dust, it contains very little soot or other soiling ingredient, and the maps can be preserved free from deterioration without difficulty.

The issue of proofs or incomplete copies is guarded against by stamping every sheet with an embossed die bearing the name of the Department. Copies are issued free of charge to all Government administrations, and these are stamped with "Official copy" in addition to the embossed stamp.

CHAPTER XIX.

Further Development of the Present Cadastral Survey.

In examining any cadastral survey the two main divisions of the subject are, firstly, what the actual state of it is, and secondly what improvements are practicable. The first of these has for the present survey been fully set forth in the preceding chapters; the second may now be briefly alluded to.

By the end of 1907 the whole of the cultivable lands had been surveyed on a large scale, the land-registers had been compiled, and the maps had been printed. With the aid of these the re-assessment of the land-tax had been completed throughout the country. A second order triangulation had been carried out throughout the whole area except the northern portion of Gharbia province, and triangulation of the third and fourth orders was nearly as far advanced. There still remains a considerable amount of work to be done before the whole of the country will have been included in a cadastral survey which is based upon an accurate triangulation, is of a uniform standard of accuracy, and is shown on maps of a uniform scale.

The most important task is a thorough revision of the triangulation; it had to be done as rapidly as possible, and many of the marks were placed in too accessible positions so that a proportion of them have been lost either by accident or more often by wilful interference; the computation should be revised with the aid of the most recent values of the standards of length, and the re-measurements of the base-lines with improved apparatus, which is now being carried out. It is most important for the economical revision of land-measurement and maps in the future that all triangulation marks of the first and second order networks should be as safe as possible from such accidental or wilful interference, and all of them must be set in masonry below the surface of the ground and so removed from sight; in a country where the whole of the ground is cultivated it is hardly possible to ensure absolute permanence for those of the third and fourth orders, since high roads are few and canal banks are frequently altered.

The second order triangulation had first to be completed in Gharbia, which has been nearly done at the end of 1908; then the whole of the network needs inspection in order that marks which have been removed or lost may be replaced. Such losses have not been infrequent, and in a recent inspection of marks in Girga province seventeen out of eighty-three were found to be missing. Owing to the re-modelling of canals, and the execution of irrigation works, as well as the erosion of the river banks by the Nile, there must always be a certain amount of risk to the triangulation marks placed in or near the cultivable land. It is therefore very necessary to carry up the valley a chain of triangulation of the first order of accuracy having longer sides than the triangles of the second order, and by which the latter can be controlled; the points of this triangulation can be placed on the rock desert and from these accurately determined positions any second order points can be replaced that may be necessary. About 200 kilometres of this work have been completed at the present time * from Cairo to Beni Suef, and, so far as the work has been critically investigated, it is found to be of the desired accuracy and of not too high a cost, so that it will be carried on gradually thus furnishing an effective and essential control of all other work. It was hoped that the signals which mark the first order stations in the desert would not be interfered with, but the curiosity of the nomad arabs has already led to several of them being damaged.

The points of the third and fourth order triangulation have also suffered by removal and interference and will need inspection and replacing as soon as the network now in course of being observed in Gharbia province has been completed. It is of the utmost importance for the rapid, accurate, and economical revision of survey work that the triangulation network should be maintained in as thoroughly efficient a state as possible.

The revision of the cadastral survey of Sharqia province was finished in 1908, and that of Beheira is now in hand, both of these provinces having been originally surveyed by the State Lands Survey in 1892–97 when the requirements were different and less complicated, and when graphic triangulation with plane-tables sufficed to furnish points for the detail measurement. After these two provinces have been

* December, 1908.

revised those of Gharbia and Menufia will also need revision, since neither of these was originally surveyed with the effective control of a reliable triangulation. Giza province, too, which was surveyed with the aid of a triangulation of inferior precision, must also be revised in its turn before the whole of the country is represented on large-scale maps of a uniform standard of accuracy.

The detail survey can also be improved, since rapidity of work is no longer the primary consideration. It would be well to revise the conventional signs in use so as to render them more convenient for purposes of land registration in the event of this being introduced at some future date. The villages, too, are now being shown in greater detail and as the country is ever becoming more densely populated and every portion of the cultivable land is being reclaimed as fast as circumstances will admit, considerable care and judgment are required to show the necessary details on the maps without overcrowding them or sacrificing clearness. The Arabic writing is somewhat of an obstacle to such reforms at it does not possess the numerous different types of letters that are available in European writing, and consequently the maps may easily become confusing to read. But a thoroughly satisfactory result in the production of maps of landed property will be largely dependent on the obligatory provision of marks being placed so as to define the boundaries of the properties. In such a country as Egypt where topographical features rarely form the boundaries of plots, it is indispensable that such boundaries should be defined by permanent marks if the full value is to be obtained from the work of an accurate technical survey.

It has already been pointed out that both the present Cadastral Survey and that of 1878–1888 have been controlled by the fiscal requirements of the country, while their value for the registration of property and for confirming the titles of landowners to their lands was a secondary consideration. But the full value of the elaborate triangulation which has been carried out during the past ten years will not have been obtained until the accurate land-measurements have been utilized for furnishing landowners with a more efficient means of recording their property than exists at present.

But for this to be done satisfactorily some few modifications must be made in the present procedure in order to meet the legal requirements of the situation. Exactly what these will be cannot be stated

until the detailed procedure of registration has been worked out, since the special conditions and customs of the country must be taken into consideration ; but although local peculiarities may necessitate modifications the general practice of cadastral surveyors in other countries will certainly be found to go far towards meeting the requirements here. For this reason, therefore, it will be instructive to examine the methods which are in use at the present time in two or three European countries where registration of title to land is already practised. In most of them, voluminous and elaborate regulations exist laying down how all surveying and measurement in connection with landed property is to be carried out ; but these details must depend on the local conditions and are represented in this country by the Technical Instructions of the Survey Department. In the general procedure it is not difficult to foresee already certain changes which will have to be made to meet the legal requirements of any effective system of land registration.

Many countries have established registration of title to landed property of recent years, and the tendency of modern legislation is to institute fuller and more complete publicity for the rights which exist over such property. For this a cadastral survey is not an absolute necessity, but it greatly facilitates the location and the accurate description of land, so that the two are now always combined or at least are very closely connected. The introduction of such a system into Egypt would be of the greatest value to landowners,* and a commission of the Mixed Tribunals has been since 1904 considering the propositions put forward by the Egyptian Government. Recently this commission having approved a scheme, the Egyptian Government has applied to the Powers that it may be sanctioned.

The system of triangulation which exists to-day throughout the cultivable portion of Egypt is amply sufficient both in accuracy and in the number of points to control all the measurements necessary for the constitution of land-registers in conformity with legal requirements if it is kept in a serviceable condition, and the lost points are regularly replaced. In the greater part of the country the fourth order points have still to be laid down, for they have only recently been introduced, but this is a simple operation, since they are controlled by the third order network. So many points of the theodolite traverses

* See "Report of the Judicial Adviser for 1907." Cairo, 1908.

have been lost or removed that the traverse lines will in most cases have to be run again, and as village boundaries have been defined and mapped by the present survey the new traverses can be more suitably located than was previously possible. The points should be placed in a more permanent manner than hitherto, when the rapidity of work which was demanded prevented more time being given to marking points; whenever the new system is introduced more effective legal powers may be available to safeguard survey marks than now exist.

In the detail survey two modifications are of primary importance: the definition of the boundaries of all plots by permanent marks and the computation of areas by mensuration instead of by graphical methods. The first of these can only be put into force with the consent of the Powers who have rights under the Capitulations; the second is already in practice in a portion of Beheira province which is under revision, with the view to ascertaining the cost of the work and the rate at which it can be carried out. It has not been more widely introduced since it renders the work slower and for the moment it is more important to provide accurate maps of the provinces which were surveyed before 1899, than to survey a small portion in the highly detailed manner that legal registration of title demands. Whenever a system of land-registration can be rigidly applied to all dwellers in Egypt irrespective of nationality, a complete revision and re-measurement of their lands will have to be made in order to constitute the land-registers; it does not therefore seem to be economical to introduce generally the preparation of dimensioned plans of each holding and to compute the area from these at a time when the question is under the consideration of the Powers, when no landowner can yet be required to mark his boundaries in a permanent manner, and when the results have no legal authority but are at most evidence of the state of things existing at a certain date.

As soon as legal authority does exist the necessary changes can be introduced in the cadastral survey at once, and the preparation of the new plans and land-registers in conjunction with the judicial authorities can be proceeded with without delay, indeed much more quickly than disputed questions of title can be investigated and decided.

It will be sufficient to describe the salient points in the cadastral surveys of a few European countries and to note the directions in

which the Egyptian Cadastre differs from them in the technical work of the surveyor.

Switzerland has recently decided to give a uniform character to the land-registration in the different cantons * and steps are being taken to put this into force. Measurement of the land is to take place before the introduction of the new land-registers, but in cases where a sufficiently accurate statement of the landed property exists the Federal council may agree to the formation of the register preceding the land measurement.

The survey of Switzerland is divided between the Federal Survey, (Landesaufnahme,) and the cadastral services of the cantons. The federal service carries out the triangulation and publishes topographical maps on scales of 1 : 250,000, 1 : 100,000 and 1 : 50,000 of mountainous regions or 1 : 25,000 of the more level portions. No map of a larger scale than this last is printed and published. The cadastral services of the cantons utilize the federal triangulation, and on it carry out the minor triangulations on which all the large scale surveys are based ; the scales employed by them are usually 1 : 250 for towns, 1 : 500 for suburbs and 1 : 1,000 for open country. These maps exist in the original only, but can be consulted at the Cadastral Office at the Hôtel de Ville and copies of them are furnished when required. They are drawn on large sheets of paper and are very neatly inked in and coloured, the work being very finely executed. The Canton of Geneva may be taken as an instance, since the cadastral survey and the land-registers there are well advanced. It contains 48 villages (communes) of various sizes, from 142 hectares (338 feddans) up to 1,909 hectares (4,544 feddans) and the whole area amounts to 24,596 hectares (58,550 feddans). It is thus of about the same size as a small district (markaz) in Egypt, but since the houses and town-property are included in the cadastral registers there is a large category of properties to be dealt with which is not yet included in the Egyptian land registers. On the other hand, the field properties are larger than in this country.

Here, as in the other cantons the triangulation executed by the Federal Survey (Landesaufnahme) is used as the basis and the control of the large-scale maps which are required for dealing with questions of

* "Code civil Suisse du 10 Décembre, 1907, Titre final, §§ 38-42."

property, so that only the fourth order triangulation, and very occasionally some of the third, has to be carried out by the cadastral staff.

A law of December 20, 1893 for the Cadastre of the town and commune of Geneva laid down that a general map of the commune was to be prepared on the scale of 1 : 10,000, the detailed plans of the commune were to be on the scale of 1 : 1,000 or 1 : 500 for the portions that were full of detail or which would probably be developed; the detailed town plans were to be on the scale of 1 : 200; the scale of 1 : 250 is now employed.

A cadastral unit is defined by Art. 5, which states that all the lands of a landowner which are in the commune form a single plot if they are not separated by a street, road, river, or by land belonging to another person. Nevertheless, when a property is composed of several distinct portions, these may be considered as separate plots. The boundary of each such plot and all marks or boundary stones are shown on the cadastral plans. The marking of the plots is effected by dressed stone blocks, usually of granite, 0·60 to 0·70 metre long with heads about 0·13 metre square. These must be placed at each change of direction of a boundary, at two points on each curve and at distances of not more than 50 metres apart on straight lines. The cost of such marking was borne by the canton.*

The triangulation, as already mentioned, starts from the points fixed by the Federal Survey and additional points are determined until there are about twelve per square kilometre, and traverses not longer than 1,200 metres are necessary to join point to point and to provide additional marks from which the detail survey may start. It is laid down that each side of a triangle must have its length determined twice by independent observations, and that each angle is to be measured three times in each position of the telescope. The permissible error of closure in a triangle is 6″·5 or 13″ as a maximum. The observations are to be reduced by the method of least squares and the mean error of co-ordinates should not in general exceed 0·015 metre. (Art 32, 34).

In the open country, the traverse lines, so far as possible, follow the boundaries of properties; in towns, they run parallel to the margin of the street, and where the street is wide the line is to be on one side of

* These rules and instructions are taken from "Loi et Règlement pour la confection du Cadastre de la ville et commune de Genève." Genève, 1894.

it, points being determined from it on the other side for the detailed measurement. (Art. 37).

The average number of points per hectare will be from 4 to 8, but such a number must refer to the work in the centre of towns where properties are small and closely crowded together. At each cross-roads or intersection of streets, a polygon point is placed. (Art. 38).

In Geneva these points are indicated by cast iron markes set in the concrete paving of the side-walks.

In the same polygon the sides are made, so far as possible, of the same length, and are not to be longer than 150 metres; if they have to be longer intermediate points are fixed especially at intersections of streets. In towns when centring apparatus is not employed with the theodolite the sides may not be shorter than 50 metres. Each side is measured twice with rods, and the maximum difference allowed between two measurements of a side is 0·02 metre. In general the permissible difference is $\sqrt{b}$ millimetres where b is the length in metres. (Art. 39).

The angles are measured once in each position of the telescope, and in towns centring tripods are to be used for the theodolite. The mean error of an angle measured with the aid of centring apparatus should not exceed from 6″·5 to 13″; for traverses observed without centring apparatus it should not exceed 16″ for the principal polygons and 32″ for the subsidiary ones. The maximum error of closure of the polygons is, therefore, in corresponding cases 6″·5, 13″, 16″, or 32″ multiplied by $\sqrt{n}$ where n is the number of angles measured. This error is distributed equally among all the angles. (Art. 41).

The linear discrepancy of closure in the co-ordinates in terms of the errors fy and fx is calculated by the formula $\sqrt{fy^2 + fx^2}$. In towns this discrepancy may not exceed from one to two hundredths per cent. of the direct distance between the ends of the polygon; on other land the limit is one fortieth per cent. Such discrepancy is distributed proportionally to the lengths of the sides. (Art. 44, 45).

Areas are calculated twice, the first time by mensuration, and the second time by the planimeter. The permissible differences between the results of these two operations are :—

$0{\cdot}05\sqrt{A}$ for the scale of 1 : 250
$0{\cdot}1\sqrt{A}$ „ „ „ „ 1 : 500
$0{\cdot}2\sqrt{A}$ „ „ „ „ 1 : 1,000

where A is the area, the unit being a square metre.

The area-computation will be checked by taking groups of about 12 plots and also by comparing the total area of the plots in a sheet with the computed area of the sheet. The permissible differences are then :—

$0{\cdot}09\sqrt{A}$ for the scale of 1 : 200 or 1 : 250
$0{\cdot}18\sqrt{A}$ „ „ „ „ 1 : 500
$0{\cdot}36\sqrt{A}$ „ „ „ „ 1 : 2,000

The maps are drawn on sheets of hand-made paper 100 by 70 centimetres and are plotted from rectangular co-ordinates, no special projection being employed ; it is laid down that distances measured on the plan should not differ from the corresponding distance measured on the ground by more than $4\sqrt{L}$ to $12\sqrt{L}$ millimetres where L represents the distance in metres. Copies of such portions of these plans as are required for purposes of registration are prepared from these originals by means of tracing paper, or in some cantons by pricking through the original sheet.

The Cadastre of Prussia may also be referred to since in the northern part of the country it has to deal with level alluvial plains on which the holdings have much in common with those of Egypt. The occurrence of extremely long and narrow plots in this part of the country has already been alluded to.

The Prussian Cadastre like that of other countries is based on the geodetic triangulation of the country, and on the second and third order triangulations dependent on it. The geodetic net-work consists of triangles having sides over 20 kilometres in length, while those of the second order and third order are from 10 to 20 and from 3 to 10 kilometres long respectively ; sides less than 3 kilometres in length occur in the fourth order triangulation. The density of triangulation points is sufficient to furnish on the average one triangulation point of any order for every 25 traverse points but the number of these in any area must depend largely on the nature of the ground, and on the size of the holdings.

Angles are as a rule measured by observing a series of arcs, each observation being made with the telescope—both positions. The necessary number of arcs or repetitions are :—

for stations for the III order 4 arcs or 6 repetitions
for „ „ „ IV „ 3 arcs or 4 repetitions ;

the permissible errors in the direction of sides are fixed at 15″ for triangles of the third order, and 25″ for those of the fourth.

The number of traverse points varies considerably with circumstances, but the following table, in which the average area per traverse point is shown, is given as a guide :—

If the plots contain on average	Woods, Marshes and Waste Lands.	More than 50 Ar.	50 — 5 Ar.	Less than 5 Ar especially in towns, etc.
i.e., if the mapping is on scale...	1 : 4,000	1 : 2,000	1 : 1,000	1 : 500
	Hectares.	Hectares.	Hectares.	Hectares.
I. Open or level country without obstacles	15	7·5	3·0	1·0
II. Moderate conditions	10	5·0	2·0	0·75
III. Cut up or intersected, or with exceptional obstacles	5	2·5	1·0	0·5

Traverse lines should be as straight as possible, and the sides should not vary greatly in length. Each side is measured twice, the steel bands or rods being read to the nearest even number of centimetres ; the two measurements may not differ more than is allowed in the following formulæ* where d is the permissible difference and L is the length of the line in metres :—

On level and favourable ground $d = 0{\cdot}01 \sqrt{4\ L + 0{\cdot}005\ L^2}$

On moderate ground $d = 0{\cdot}01 \sqrt{6\ L + 0{\cdot}0075\ L^2}$

On difficult or hilly ground $d = 0{\cdot}01 \sqrt{8\ L + 0{\cdot}01\ L^2}$

The closing angular error may not exceed $1{\cdot}5 \sqrt{n}$ minutes of arc where n is the number of angles observed.

The linear closing error $fs = \sqrt{fy.\ fy + fx.\ fx}$ may not exceed : *

I. Favourable conditions $d = 0{\cdot}01 \sqrt{4\ [L] + 0{\cdot}005\ [L]^2}$

II. Moderate conditions $d = 0{\cdot}01 \sqrt{6\ [L] + 0{\cdot}005\ [L]^2}$

III. Unfavourable conditions $d = 0{\cdot}01 \sqrt{8\ [L] + 0{\cdot}005\ [L]^2}$

where [L] is the sum of the lengths of the sides in metres.

The principal chain-lines are measured between points which have been determined by the triangulation and the difference between the

* These are the formulæ in use in controlling similar work in Egypt, see page 220.

computed and measured distance may not exceed the following limits:

for flat ground $d = 0{\cdot}01\sqrt{4S + 0{\cdot}005S^2}$
for moderate ground $d = 0.01\sqrt{6S + 0{\cdot}005S^2}$
for rough ground $d = 0{\cdot}01\sqrt{8S + 0{\cdot}005S^2}$

where S is the distance in metres.

All traverses are run with a theodolite except in special cases, such as woods, copses, etc., where a compass may be used. In this case the sides must be as nearly equal as possible, and none of them may be more than 100 metres long.

Areas are computed first by mensuration from the field-measurements, but the second computation may be by means of a planimeter; if the area of a group of plots belonging to the same owner is computed, then the areas of the separate plots may be taken out graphically. Plots of 100 square metres or less are, however, always computed. On re-survey it will frequently happen that a small difference in area is found since the area of a plot with curved boundaries may easily give slightly different results according to the number of lines measured. The permissible difference between two determinations in such cases and when comparing the area of tracts with the sum of the areas of the plots composing them is:—

$$d = 0{\cdot}01\sqrt{60\,A + 0{\cdot}02\,A^2}$$

where A is the area in square metres.

As a control the area of groups of plots is computed and compared with the sum of the plots. The first such control is by taking groups of not more than 30 plots, the second varies according to the scale of the map, and the following areas have been laid down for different cases:—

not more	than	60	hectares	for	maps	on	the	scale	of	1 :	4,000
,,	,,	,,	20	,,	,,	,,	,,	,,	,,	1 :	2,000
,,	,,	,,	5	,,	,,	,,	,,	,,	,,	1 :	1,000
,,	,,	,,	1	,,	,,	,,	,,	,,	,,	1 :	500

Larger control areas are obtained by dividing the map-sheets into squares of one decimetre side, so that these squares and afterwards the sheet squares can be compared with the sum of the plot areas within them.

The cadastral surveys which have just been referred to preserve their maps as originals only and copies are made of such portions as are

required by landowners for the registration or transfer of their property. In the Grand Duchy of Wurtemberg, however, the maps are all lithographed and sold to the public, as is the case also in Austria.

In Würtemberg three orders of triangulation are employed, the first having sides from 10 to 75 kilometres long, the second of 4 to 30 kilometres, while the sides of the third order vary from 5 to 0.7 kilometres in length. The first two orders are computed for a spherical surface 274 metres above sea-level, but plane trigonometry is used for the third order triangulation computation. When it is necessary to extend the triangulation which is already controlled by the network of the first and second orders, two to four arcs are usually taken when observing from any such additional point; for intersection of other points not less than three or more than six observations are to be employed, and for resection not less than four nor more than eight.

The theodolite traverses are either main or subsidiary; the former are carried as directly as possible from one triangulation point to another, while the latter follow the features of the ground. They may not be more than 1,000 metres long as a rule, and the sides may not be more than 500 nor less than 50 metres in length. The angles are observed once in each position of the telescope.

Areas are computed from field measurements, and also measured graphically; the permissible difference between such determinations on the scale of 1 : 1,250 for level ground is:

$$d = 0{\cdot}25 \sqrt{A} + 0{\cdot}00075\ A$$

where A is the area in square metres; for maps on the scale of 1 : 2,500 it is one and a half times larger, and the angular error of closure may not exceed $1.5 \sqrt{n}$ minutes where n is the number of angles measured. The sides are measured with rods, which are compared frequently with a standard and are not allowed to vary more than 1.6 millimetre in the case of a 5-metre rod nor more than 1.3 millimetre for a 3-metre rod. The linear error of traverse on level ground may not exceed:—

$$d = 0{\cdot}01 \sqrt{[L]} + 0{\cdot}0005\ [L^2] + 0{\cdot}1 \sqrt{n-1} \text{ in metres}$$

where [L] is the sum of the lengths of the sides and n is the number of the sides.

The scale used for the maps is 1 : 1,250 for towns and villages and 1 : 2,500 for the open country, all sheets being lithographed on stone and sold to the public.

Maps are plotted from field-books in which all detail is entered up, and dimensioned field-sketches on scales of 1 : 250, 1 : 500, 1 : 1,000 or 1 : 2,500 are made whenever it may be necessary. The map-sheets are laid out in four quadrants N.E., S.E., S.W. and N.W., and numbered for easy reference.

It will be noticed that in all the cadastral services which have been quoted different scales have to be employed according as large or small holdings predominate; it is therefore necessary to employ two or three to suit the different conditions which occur. The sheets are sometimes correctly oriented, but in other surveys may be drawn in any position.

The principal modifications, therefore, which will have to be introduced in the procedure of the present Cadastre are :—

(1) Recording the dimensions of plots so that the area may be computed from them ;

(2) Determination of areas of plots by mensuration ;

(3) Employment of larger scale plans for towns, village sites, and places where the plots are exceptionally small ;

(4) The recording of property in villages and towns which is not at present recorded in the land registers since land-tax is not imposed on it.

The form of register employed must depend greatly on the laws and customs of the country concerned, so that there is little advantage in reproducing those of many different cadastral services. As a type, however, of the kind of register which would probably have to be kept, we may take those of the canton of Geneva.

Four registers are kept at the office of the Cadastre. In the first of these the plots are recorded in serial order ; the number of the plot, a reference to the map-sheet on which it occurs, its area, any buildings situated on it, references to any entries concerning it in the mutation register, and the names of successive owners are given ; a specimen of thes register is given on p. 382-3. In the second the plots belonging to each proprietor are collected ; the number of each plot, a reference to the map-sheet, its area, the buildings which are situated on it, and references to any transfer of plots which may take place are here recorded. This is the " Registre des Propriétaires," shown on p. 384

* Apparently for work in the City only.

The third is the "Registre des Bâtiments," in which is recorded the plot in which the building stands, its ownership, any transfers which may take place, and full details concerning the building, its area, purpose, material, etc., see p. 385.

The fourth is an index of the landowners by which all information about the property of any one can be readily traced. Copies of all deeds of sale, transfers, etc., are also filed and references to them are entered in the registers so that any entry can be quickly verified. There are 24,596 hectares (58,550 feddans) in the canton of Geneva and it is divided into forty-eight communes for each of which a set of registers is kept, each of which may run into several, sometimes many volumes.

Besides these four registers which are kept for each commune, there is also a single register, "Registre des Mutations," kept for the whole canton, in which all transfers of land from one owner to another are recorded (see p. 386). A page is allotted to each one and a complete summary of the circumstances and references to the official documents are given. These include the name of the commune, the number of the plot or plots, the cadastral numbers of any buildings there may be, the date of the deed, references to the registers where a copy of it is filed, the names of the parties concerned and any other special information. Every such transfer of land must be accompanied by a copy of the portion of the cadastral map showing the land. This is copied from the cadastral map, which only exists in original at the cadastral office, by a licensed surveyor who having made the copy adds to it the additions, alterations, etc., that may be needed and is solely responsible for the correctness of the plan. The cadastral officials merely verify the accuracy of the copy of their plan and not that of the additions made to it. In this manner both the cadastral maps and registers are kept constantly up to date, since every transfer has to be registered in the cadastral office before it is valid. A specimen of such a modified extract from the cadastral maps is given in Plan XXX.

COMMUNE

NUMÉROS SUIVIS	INDICATION du NUMÉRO et de la partie de la FEUILLE où se trouve la parcelle	CONTENANCES — MESURES MÉTRIQUES — Hectares	Ares	Mètres	Décim.	BATIMENTS — SITUATION	NUMÉROS D'ORDRE des Articles du Registre des BATIMENTS concernant la parcelle	ORIGINE du NUMERO — PARCELLES antérieures dont a été formé la parcelle dont s'agit	DATE et NUMÉRO D'ORDRE de la mutation qui à donné lieu à la CRÉATION de la parcelle	DISPARITION du NUMERO — PARCELLES postérieures formées par la parcelle dont s'agit	DATE et NUMERO D'ORDRE de la mutation qui a donné lieu à la DISPARITION DU NUMERO de la parcelle	OBSERVATIONS
									Du — 19 — N° — Vol. —		Du — 19 N° — Vol.	

Supplément aux Désignations

D

DÉSIGNATION DES PROPRIÉTAIRES SUCCESSIFS

Avec la date et le numéro d'ordre de la mutation qui a donné lieu à leur inscription au cadastre

NUMÉRO D'ORDRE DU COMPTE OUVERT À CHAQUE PROPRIÉTAIRE SUCCESSIF

SUR LE REGISTRE DES PROPRIÉTAIRES

des Propriétaires successifs

REGISTRE DES PROPRIÉTAIRES

NUMÉRO D'ORDRE DU COMPTE PRÉCÉDENT, OUVERT AU NOM DU MÊME PROPRIÉTAIRE

N°

Compte ouvert à

N°

NUMÉROS DES PARCELLES	NUMÉRO DE LA FEUILLE où se trouve la parcelle	CONTENANCES Mesures métriques				BATIMENTS		DATE ET NUMÉRO D'ORDRE DE LA MUTATION qui a donné lieu à l'insertion de l'article dans le compte dont s'agit	OBSERVATIONS
		Hectares	Ares	Mètres	Décim.	SITUATION	NUMÉRO D'ORDRE des articles du Registre des bâtiments concernant la parcelle		
								Du 190 N° Vol	

DE LA COMMUNE D

NUMÉRO D'ORDRE DU COMPTE SUIVANT, OUVERT AU NOM DU MÊME PROPRIÉTAIRE

N°

NUMÉROS DES PARCELLES	DATE ET NUMÉRO D'ORDRE DE LA MUTATION qui a fait sortir du compte dont s'agit tout ou partie de la parcelle.	NOMS DU OU DES NOUVEAUX PROPRIÉTAIRES AU COMPTE DE QUI LA PARCELLE PASSE EN TOUT OU EN PARTIE — NUMÉROS D'ORDRE DE CES COMPTES
	Du 190 N° Vol.	

REGISTRE DES BATIMENTS

Commune d .....

N° .....

NUMÉRO DE LA PARCELLE	FEUILLE	CONTENANCE DE LA PARCELLE				SITUATION	ORIGINE DE L'ARTICLE		DISPARITION DE L'ARTICLE	
		Hectares	Ares	Mètres	Décim.		DATE DE LA MUTATION	N° D'ORDRE DE L'ARTICLE ANTÉRIEUR	DATE DE LA MUTATION	N° D'ORDRE DE L'ARTICLE POSTÉRIEUR

NOMS DES PROPRIÉTAIRES SUCCESSIFS

Détails relatifs à chaque bâtiment en particulier.

NUMÉROS DES BATIMENTS	SURFACE			NATURE		MENTIONS RELATIVES : 1. Au mur mitoyen ; si ce mur n'appartient pas par parties égales aux propriétaires voisins. 2. Aux droits de l'Etat ; si ce bâtiment est construit sur le domaine public. 3. Aux droits réciproques des propriétaires ; si ce bâtiment appartient à plusieurs propriétaires ayant des droits distincts. Autres observations.
	Ares	Mètres	Décim.	DESTINATION	MATÉRIAUX	

REGISTRE DES MUTATIONS

N° _____

NOM DE LA COMMUNE où a lieu la mutation	NUMÉROS DES PARCELLES qui font l'objet de la mutation	NUMÉROS CADASTRAUX DES BATIMENTS qui font l'objet de la mutation	DATE DE L'ACTE TRANSCRIT	NOM DE L'OFFICIER PUBLIC rédacteur de l'acte transcrit	VOLUME ET NUMÉRO de l'article correspondant du registre des transcriptions	NUMÉROS D'ORDRE DES AUTRES ARTICLES du registre des mutations tirés du même article du registre des transcriptions	NUMÉRO DU PLAN accompagnant l'acte transcrit
			Du _____ 19		cc Vol. _____ N°		

Nature et Objet de l'Acte transcrit : _____

Désignation succincte du propriétaire du chef duquel la mutation est opérée	Noms, Prénoms, Prénoms du père, état ou profession et domicile du ou des NOUVEAUX PROPRIÉTAIRES OBSERVATIONS
	à

Certifié conforme au Registre des Transcriptions,

Genève, le _____ *19* _____ *Le Conservateur soussigné,*

TABLEAU DE LA MUTATION

indiquant le détail des divisions et réunions, dont le certificat a été transmis au Conservateur des Hypothèques le _____ *19* _____

Mutation opérée sur les registres du cadastre et collationnée.

LE CONSERVATEUR.

APPENDICES.

APPENDIX I.

DÉCRET

Du 10 août 1879, fixant les attributions du Cadastre.

NOUS, KHÉDIVE D'EGYPTE,

Sur la proposition du Notre Conseil des Ministres ;
Décrétons et promulgons ce qui suit :

ARTICLE PREMIER.

Afin d'assurer une égale répartition de l'impôt foncier entre tous les contribuables, proportionnellement à la valeur des biens que chacun d'eux possède, il sera procédé à la confection d'un Cadastre général, c'est-à-dire à la levée des plans et à la classification des terrains de la Haute et de la Basse Egypte.

ART. 2.

Le service du Cadastre constituera une administration distincte relevant du Ministère des Finances ; la direction en sera confiée à un Directeur Général nommé par décret, sur la proposition du Conseil des Ministres. Les Inspecteurs du service seront nommés par arrêté Ministériel sur la proposition du Directeur Général. Tous les autres employés du service seront nommés directement par le Directeur Général.

ART. 3.

Le Directeur Général dirigera toutes les opérations cadastrales et tous les services dépendant de son administration.

A cet effet il a qualité pour rédiger et mettre en exécution tous règlements d'organisation, d'attributions et de discipline.

ART. 4.

En aucun cas les opérations cadastrales ne pourront préjuger les questions de propriétés ni préjudicier aux droits des particuliers.

Art. 5.

Après l'achèvement des travaux d'art, il sera procédé à la classification des terrains. Les experts classificateurs détermineront en combien de classes chaque nature de propriété doit être divisée à raison des divers degrés de fertilité des terrains et de la valeur des produits.

Art. 6.

Les réclamations qui concernent les opérations de délimitation et de classification ayant un caractère purement administratif seront adressées hiérarchiquement aux Agents du Cadastre et seront décidées en dernier ressort par le Ministre des Finances sur l'avis du Directeur Général.

Art. 7.

La minute du plan parcellaire et le registre dans lequel seront inscrits les terrains au moment des opérations cadastrales, seront conservés aux archives du Ministère des Finances ; il en sera fait deux copies conformes : la première dressée par la Moudirieh sera déposée au chef-lieu de chaque Moudirieh et confiée à un employé, responsable de sa conservation ; cet employé sera nommé par le Directeur Général du Cadastre et résidera à la Moudirieh sous les ordres du Moudir ; la seconde copie sera générale et restera déposée à la Direction du Cadastre.

Art. 8.

Toute personne aura le droit de prendre communication des registres et des plans du Cadastre, soit dans les Moudiriehs, soit à la Direction Générale.

Il sera délivré, à tous intéressés qui en feront la demande, copie d'une ou de plusieurs des parcelles cadastrées moyennant le paiement préalable d'un droit qui sera ultérieurement déterminé.

Art. 9.

Deux jours au moins avant qu'il soit procédé aux opérations d'arpentage ou classification dans un district (Kism), la Direction Générale en préviendra le public par un avis publié au chef-lieu du Kism et dans les principaux Beleds.

Il sera loisible aux propriétaires, fermiers, régisseurs et à tous intéressés d'assister tant aux opérations de l'arpentage qu'à celles de la classification et de présenter leurs observations.

Art. 10.

Les Moudirs, Nazirs-el-Kisin, Cheikhs-el-Beled, Sarrafs, Agents de l'Autorité et fonctionnaires de tout ordre et de tout rang seront tenus de fournir aux Agents

du Cadastre tous les renseignements qui leur seront demandés et de les aider, chacun dans la limite de ses attributions, dans l'accomplissement de leur mission.

Les Inspecteurs et Agents du Cadastre s'entoureront de tous les renseignements qu'ils pourront recueillir et entendront toutes les personnes dont les indications pourraient se rattacher utilement aux opérations cadastrales qui leur sont confiées.

Art. 11.

Une Commission dont l'organisation et le fonctionnement seront ultérieurement déterminés par le Ministre des Finances sur la proposition du Directeur Général, procédéra à la révision du classement des terrains.

Les formes et conditions dans lesquelles les intéressés seront avertis des décisions de la Commission et pourront se pourvoir contre elle, seront ultérieurement déterminées.

Art. 12.

Toutes dispositions des codes, lois et règlements, tous usages, coutumes et traditions contraires au présent décret, seront considérés comme nuls et non avenus.

Notre Ministre des Finances est chargé de l'exécution du présent décret.

Fait à Alexandrie, le 10 août 1879.

MEHEMET THEWFIK.

Le Président du Conseil des Ministres,
CHÉRIF.

Le Ministre des Finances,
ISMAIL PACHA EYOUB.

DÉCRET

Portant réduction de 216.000 L.E. par an sur l'impôt foncier, de 1898 à 1907

NOUS, KHÉDIVE D'EGYPTE,

Vu les articles 1, 2 et 3 du décret du 12 juillet 1888 ;

Sur la proposition de Notre Conseil des Ministres et avec l'assentiment des Puissances signataires de la Convention de Londres du 17 mars 1885 ;

Avons décrété et décrétons :

ARTICLE PREMIER.

A partir de l'exercice 1898 et jusques et y compris l'année 1907, l'impôt foncier sera, sous la réserve de l'assentiment annuel de la Caisse de la Dette, réduit d'une somme de 216.000 L.E. par an.

Les réductions seront effectuées pour chaque province d'après l'état ci-annexé.

ART. 2.

La somme nécessaire au dégrèvement autorisé par l'article premier figurera dans les comptes du Gouvernement comme une recette affectée. Elle sera imputée en première ligne sur le montant des coupons des titres appartenant au fonds de réserve (sans qu'il soit préjudicié aux engagements de garantie qui grèvent ou grèveront les titres), et en seconde ligne sur la part prise par ce fonds, jusqu'à concurrence du quart de cette part, dans les excédents de l'année précédente.

ART. 3.

Dans le cas où le montant des coupons des titres et le quart de la part prise par le fonds de réserve dans les excédents n'atteindraient pas, dans une année quelconque, le chiffre de 216.000 L.E., le Gouvernement aura la faculté ou de supprimer les réductions pour la dite année, ou de les effectuer en comblant la différence sur les recettes non-affectées.

ART. 4.

Notre Ministre des Finances devra s'adresser chaque année, après la clôture des comptes de l'année précédente, à la Caisse de la Dette pour obtenir son assentiment.

Il lui fournira les justifications qu'elle demandera concernant l'emploi du crédit fixé dans l'article premier, ainsi que les renseignements nécessaires sur l'avancement des opérations cadastrales préalables à la péréquation des impôts, et sur le résultat de la péréquation, par augmentation et diminution, au fur et à mesure de la clôture des opérations partielles.

Art. 5.

Les Commissaires de la Dette ne pourront refuser leur assentiment que dans le cas où les conditions indiquées dans les articles 1, 2 et 3 ne seront pas remplies, ou bien si le Gouvernement refusait de donner les justifications ou de fournir les renseignements prévus par l'article 4.

Art. 6.

Notre Ministre des Finances est chargé de l'exécution du présent décret.

Fait au Palais d'Abdine, le 26 Novembre 1898.

ABBAS HILMI.

Par le Khédive:

Le Président du Conseil des Ministres,
Moustapha Fehmy.

Le Ministre des Affaires Étrangères,
Boutros Ghali.

Le Ministre des Finances,
Ahmed Mazloum.

Etat des sommes à dégrever.

Moudiriehs	Superficie	Montant du dégrèvement
	Feddans.	L. E.
Basse-Egypte		
Kallioubieh	4.971	1.558
Charkieh	41.539	9.940
Dakahlieh...	105.012	28.431
Gharbieh	163.051	48.200
Menoufieh	9.099	3.148
Behéra	82.198	24.516
Total...	405.870	115.793
Haute-Egypte		
Guizeh	45.827	8.607
Beni-Souef	109.755	24.824
Fayoum	51.302	13.785
Minia...	94.812	20.738
Assiout	178.333	21.912
Guirga	66.500	9.086
Kéna...	5.986	867
Howdoud...	2.683	384
Total...	555.198	100.203
Total général...	961.068	215.996

RÈGLEMENT *

Du 13 avril 1899 relatif aux opérations de l'Arpentage.

1° Le service technique de l'Arpentage est chargé de faire les « Mizaniehs » dans les villages mêmes ; ces registres doivent être préparés dans l'espace d'un mois à partir du jour où l'on aura achevé la vérification des superficies données par l'Arpentage, à moins qu'il n'y ait des raisons spéciales pour prolonger ce délai, ce qui doit toutefois être autorisé par un inspecteur de l'Arpentage.

2° Les états de « Tafrigh » faits actuellement par le Service Technique de l'Arpentage, seront désormais préparés en prenant en considération le total des superficies constatées, lors de l'arpentage, au nom de chaque détenteur, et ce au lieu du système actuellement adopté qui consiste à prendre le total des superficies portées sur le Moukallafah au nom de chaque propriétaire. Lecture devra être faite de ces états de « Tafrigh » en présence des habitants des villages.

3° Les sarrafs se joindront aux agents de l'Arpentage pour préparer les « Mizaniehs » des villages de leur serafieh ; leurs attributions seront les suivantes :

a) Indiquer d'une manière exacte les terrains de chacun des détenteurs figurant sur l'état dit « Kaschf El Saraf » d'après les indications portées sur ses registres, et ce après avoir pris note des changements qui auraient pu subvenir dans le Moukallafah après la date de l'état primitif.

b) Indiquer sur l'état les terrains qui auraient pu être pris du Zimam des villages voisins et ajoutés au village, avec mention des impôts de ces terrains. Ils indiqueront également les terrains qui auraient pu être ajoutés aux terrains d'un autre village, et ce d'après les superficies données par l'Arpentage.

c) Vérifier et s'assurer que les indications portées sur les « Mizaniehs » devant chaque nom, en ce qui concerne les taux d'impôts, les superficies de Tawalefs, etc., sont exactes et conformes aux registres de la Moudirieh.

Les inspecteurs de l'Arpentage s'entendront directement avec les Mamours Markaz au sujet du temps que les sarrafs auront à affecter pour faire ces travaux.

4° Le Service Technique de l'Arpentage enverra directement au Contrôle des Contributions Directes aux Finances, les registres d'Arpentage, de Mizanieh et de Tafrigh, des villages terminés. — Ces registres doivent être accompagnés du plan du village.

Il enverra également au Contrôle des Immeubles Libres une copie du plan de chaque village accompagnée d'un bordereau des biens appartenant à cette Administration.

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* "La Législation en matière immobilière," Ministry of Finance, Cairo, 1901, page 606.

5° Le Contrôle des Contribu ions Directes enverra au Moudiriehs respectives le registre contenant l'arpentage, le Mizanieh et le Tafrigh, afin qu'elles préparent le nouveau Moukallafah dans un délai de 30 jours.

Ce délai peut être augmenté par un ordre spécial du dit Contrôle, et ce, dans les mois où les échéances à percevoir sur les impôts sont considérables.

6° Les excédents d'arpentage qui seront constatés à la suite de l'arpentage, seront régis par les instructions spéciales *.

Les Moudiriehs auront à prendre note sur les nouveaux Moukallafahs des changements pouvant survenir à la suite de la vente de terrains de l'Etat ou de toute autre cause provenant de la mise en exécution des dites instructions, et ce dès que ces changements lui seront communiqués par le Contrôle des Immeubles.

7° La procédure contenue dans les articles 1, 2, 3, 4 et 5 des présentes instructions sera adoptée pour les villages où se poursuit actuellement l'arpentage et non terminé, comme pour les villages qui seront arpentés à l'avenir.

Le Contrôle des Immeubles doit terminer les Mizaniehs qui se trouvent maintenant entre les mains de ses agents, ainsi que les Mizaniehs des villages que le Service Technique lui a fait savoir être terminés. Ces Mizaniehs doivent être achevés dans un délai à fixer par Monsieur le directeur des Immeubles libres de l'Etat.

Quant aux villages arpentés, qui ne rentrent pas dans la catégorie visée par le paragraph 7 des présentes instructions, le Service Technique est chargé d'en faire les Mizaniehs et d'en envoyer les registres au Contrôle des Contributions Directes dans un délai à fixer par Monsieur le directeur de l'Arpentage général.

DÉCRET

Du 28 avril 1891 portant application du système mètrique décimal dans les Administrations de l'État à partir du 1er janvier 1892.

NOUS, KHÉDIVE D'ÉGYPTE,

Considérant les variations qui se sont produites, avec le temps, dans la valeur des poids et mesures égyptiens ainsi que les différences qui existent entre les divers poids et mesures usités en Égypte ;

Considérant qu'il importe que les transactions aient pour base des poids et mesures dont la valeur soit parfaitement déterminée ;

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* Voir ces instructions au Chapitre XX, Sous-Chapitre 1er, *Biens Libres*, p. 170 de la "Législation en matière immobilière."

Considérant les avantages que présente à ce point de vue le système métrique décimal des poids et mesures, ayant pour base le mètre de la Commission Internationale du mètre ;

Considérant que pour permettre l'application du système métrique sans apporter de trouble au régime des transactions ordinaires du pays, il convient de fixer le rapport des poids et mesures égyptiens avec les poids et mesures métriques d'après la valeur actuelle des poids et mesures effectivement en usage en Égypte ;

Considérant le résultat des expériences de comparaison effectuées par la Commission des poids et mesures instituée par décision de Notre Conseil des Ministres en date du 14 juin 1886 (12 Ramadan 1303).

Sur l'avis conforme de Notre Conseil des Ministres,

Le Conseil législatif entendu :

DÉCRÉTONS :

Article premier.

A partir du 1er janvier 1892, les Administrations de l'Etat appliqueront le système métrique décimal dans leurs services ainsi que dans leurs rapports avec le public.

La dénomination correspondante des poids et mesures égyptiens pourra être mentionnée en même temps que l'énonciation des poids et mesures métriques dans tous les actes publics ou documents administratifs.

Les mesures agraires continueront jusqu'à nouvel ordre à être calculées et énoncées d'après les mesures existantes, conformément aux dispositions du décret du 15 Zilcadé 1277 et du *nota bene* y annexé du 7 Chaban 1292.

Le tonnage des navires continuera également a être mesuré et énoncé suivant les règles existantes.

Art. 2.

Le mètre de la Commission Internationale du mètre est l'étalon prototype auquel seront rapportés les poids et mesures égyptiens.

Art. 3.

Le rapport métrique des poids et mesures égyptiens est fixé comme il suit :

Mesures de longueur : diraa baladi, 0 metre 58 centimetres.

Mesures de poids : dirhem, 3 grammes 12 centigrammes.

Mesures de capacité : ardeb, 198 litres.

Le rapport métrique des multiples et sous-multiples de ces unités est fixé au tableau d'équivalence annexé au présent décret.

Art. 4.

Des poids et mesures étalons seront déposés au chef-lieu de chaque Moudirieh et Gouvernorat pour permettre la vérification des poids et mesures.

ART. 5.

Nos Ministres sont chargés, chacun en ce qui le concerne, de l'exécution du présent Décret.

Fait au Palais d'Abdine, le 19 Ramadan 1308 (28 avril 1891).

MEHEMET THEWFIK.

Par le Khédive:

Le Président du Conseil des Ministres,

RIAZ.

DÉCRET

Du 15 Zilcadeh 1277 (25 mai 1861).

L'arpentage des terres aura désormais pour base l'unité de mesure appelée *kassaba*, représentant trois mètres cinquante-cinq centimètres selon la chaîne adoptée par les ingénieurs.

N.B. — Dans toute l'Egypte et ses dépendances le *feddan* est représenté par trois cent trente-trois *kassabas* et un tiers carrés, base reconnue par le Gouvernement égyptien d'après les cadastres faits du temps de feu S.A. Mohammed-Aly pacha.

Sont exceptées de cette règle depuis longues années certaines localités dont l'étendue est insuffisante à parfaire la superficie sus-indiquée pour le feddan. A l'égard de ces localités, la superficie en feddans est déterminée par les titres de propriété, la possession et l'inscription sur le rôle des contributions.

DÉCRET

Du 28 avril 1891.

ART. 1er. — Les mesures agraires continueront jusqu'à nouvel ordre à être calculées et énoncées d'après les mesures existantes, conformément aux dispositions du décret du 15 Zilcadeh 1277 et du *Nota Bene* y annexé.

APPENDIX II.

CERTIFICATES OF STANDARD OF LENGTH.

CERTIFICATE N°. 1.

No. 206.

Dated 19th July, 1898.

THIS IS TO CERTIFY that three subdivided metres, forming a standard triple metre scale (No. 25) belonging to the Geological Survey Department of Egypt have been verified at the Standard Department of the Board of Trade for Messrs. Elliott Brothers of London, and their whole lengths ascertained, in terms of the iridio-platinum and standard metre numbered 6 deposited with the Board o Trade ; as follows at 0° Centigrade :

Metre marked 1	0 =	Metre No. 6	— 0·1274	millimetre.
,, ,, 2	3 =	,, ,,	— 0·1309	,,
,, ,, 4	4 =	,, ,,	— 0·1302	,,

NOTE.—End Metre No. 6 = 1 metre + 13·2 At 0° C.

Signed: H. J. CHANEY,
Superintendent of Weights and Measures.

Standards Department,
Board of Trade.

Coefficient of linear expansion triple metres = 0·000019 for 1° C.
,, ,, ,, Metre No. 6 = 0·00000862 for 1° C.

CERTIFICATE
OF
VERIFICATIONS.

CERTIFICATE Nº. 2.

No. **333.**

Dated 18th March, 1904.

THIS IS TO CERTIFY that three Standard Measures each of 1 Metre numbered 251 and marked respectively 0 ... 1, 2 ... 3, and 4 ... 5, forming together a Triple Metre Measure, the property of the Survey Department of the Public Works Ministry, Cairo, have been verified by the Board of Trade, the temperatures of the bars under comparison being ascertained in terms of the normal Hydrogen scale by means of Tonnelot thermometers, and the observations being subsequently reduced by calculation to the normal temperature of metric measures, viz., 0º Centigrade, AND THAT their lengths at 0º Centigrade have been determined to be as follows :

0 .. .. 1 (No. 251)	= 1 Metre	— 0·006	millimetre	or 0·999994	metre.
2 .. .. 3 (No. 251)	= 1 „	— 0·005	„	„ 0·999995	„
4 .. .. 5 (No. 251)	= 1 „	— 0·012	„	„ 0·999988	„

The lengths stated above are the respective lengths at 0º Centigrade of the three several Metres as measured from end to end of each Metre and were ascertained for each metre separately and not when the Three Metres were butted together to form the Triple Metre.

The coefficient of linear expansion for each of the bars was taken as 0·0000121 metre for 1º Centigrade.

Signed: H. J. Chaney,
Superintendent of Weights and Measures.

Standards Department,
Board of Trade.

CERTIFICATE
OF
VERIFICATIONS.

CERTIFICATE No. 3.

No. **196.**

Dated 18th December, 1897

THIS IS TO CERTIFY that a subdivided Metre scale has been compared with the Standards of the Board of Trade for Messrs. Elliott Brothers and the length between its extreme dividing lines has been ascertained, in terms of the iridio-platinum linear standard metre numbered 16 deposited with the Board of Trade, to be as follows :

At 0° C = 1·00003659 Metre No. 16 at 0° C.
At 62° F = 1·00035326 Metre No. 16 at 0° C.

The verification stamp (portcullis and date) has been etched on the bar.

H.D.

Signed: H. J. CHANEY,
Superintendent of Weights and Measures.

Standards Department,
Board of Trade.

CERTIFICATE
OF
VERIFICATIONS.

CERTIFICATE N°. 4.

CERTIFICAT

d'une Règle-Etalon décimétrique, en acier-nickel, appartenant à la Direction Générale des Arpentages d'Egypte.

Description.

Cette règle, construite par les soins du Bureau international des Poids et Mesures est en acier-nickel à 36 pour 100 environ de nickel. La section est celle d'un rectangle de 21 m/m sur 7 m/m ; sa longueur totale est de 150 m/m environ. Elle porte, à son extrémité voisine du zéro de l'échelle, le numéro 41, frappé au poinçon.

La règle est divisée en millimètres sur une longueur de 100 m/m ; et porte à chaque extrémité de la division un trait supplémentaire ; elle est chiffrée de 10 m/m en 10 m/m ; à la distance de 10 m/m du dernier trait se trouve un millimètre divisé en dixièmes et prolongé des deux côtés par un trait supplémentaire. La division est recoupée par deux traits longitudinaux, situés à 0m/m.2 de distance, limitant entre eux la partie utile des traits transversaux. La règle est contenue dans un écrin en acajou portant le même numéro.

Étude.

Dilatation. — La dilatation de la réglette a été supposée égale à celle d'une règle de 1 mètre de longueur prise dans la même coulée ; les mesures de cette dernière, faites au comparateur à dilatation du Bureau international, à six températures différentes, comprises entre 0° et 38°, ont donné, pour la dilatation moyenne entre 0° et T°,

$$x = (0{,}965 - 0{,}00017\ T)\ 10^{-6},$$

exprimant la température en degrés centigrades dans l'échelle normale du thermomètre à hydrogène.

Erreurs de Division. — Les erreurs de la division ont été déterminées à l'aide d'un comparateur à déplacement longitudinal, construit spécialement pour cet objet, et muni de microscopes dont le grossissement est d'environ 200 diamètres. La réglette étant placée sur le banc mobile du comparateur, dans l'alignement d'un autre étalon du même alliage, on a comparé chacun de ses intervalles centimétriques à tous les intervalles centimétriques de l'étalon auxiliaire ; ensuite

chacun des intervalles millimétriques du premier centimètre de la seconde règle. Le même procédé a été appliqué aux intervalles du millimètre subdivisé en dixièmes. Ce millimètre a été, à son tour, comparé aux dix millimètres connus de la règle auxiliaire.

Equation. — La longueur totale du décimètre a été déterminée par une comparaison, en série fermée, avec deux autres règles du même alliage, dont l'une avait été déterminée, également en série fermée, avec cinq autres règles préalablement comparées aux dix décimètres successifs de la règle normale du Bureau international. Connaissant l'équation, on a pu rapporter enfin les erreurs de la division à la longueur totale de la règle.

Les intervalles étudiés fourniront au moins un étalon de toute longueur d'un nombre entier de millimètres, inférieure à 1 décimètre.

Le tableau suivant donne les longueurs, comptées à partir du trait 0, et à la température de 0°, de tous les intervalles de la règle.

VALEURS DES CENTIMÈTRES ET MILLIMÈTRES
DE LA RÈGLE N° 41, À 0°, COMPTÉS À PARTIR DU TRAIT 0.

Traits.	Intervalles.	Traits.	Intervalles.
0	0^{mm} $0\mu\cdot0$	10	01^{mm} + $2\mu\cdot0$
1	1 + 1·2	20	20 + 2·0
2	2 + 1·6	30	30 + 1·4
3	3 + 1·6	40	40 + 0·9
4	4 + 1·6	50	50 + 1·7
5	5 + 1·6	60	60 + 2·3
6	6 + 1·5	70	70 + 1·5
7	7 + 1·9	80	80 + 1·0
8	8 + 2·1	90	90 + 1·6
9	9 + 2·2	100	100 + 2·1

VALEURS DES DIXIÈMES DE MILLIMÈTRE,
À 0°, À PARTIR DU PREMIER TRAIT DU MILLIMÈTRE.

Traits.	Intervalles.
0	$0\cdot0^{mm}$ $0\mu\cdot0$
1	0·1 + 0·3
2	0·2 + 0·4
3	0·3 + 0·5
4	0·4 + 0·2
5	0·5 + 0·0
6	0·6 + 0·0
7	0·7 + 0·1
8	0·8 + 0·3
9	0·9 + 0·2
10	1·0 — 0·1

Le Directeur du Bureau,
(Signé) RENÉ BENOÎT.

Le 30 Avril 1900.

CERTIFICATE N°. 5.

BUREAU INTERNATIONAL
DES
POIDS ET MESURES

Pavillon de Breteuil, Sèvres.

Le 12 Décembre 1903.

CERTIFICAT

d'un Etalon géodésique de 5 mètres appartenant au Service des Arpentages d'Egypte.

Description.

L'étalon est constitué par l'ensemble de deux règles, respectivement en platine et en laiton, superposées et portées sur une série de rouleaux fixés au sommet d'un support en fer en forme de ⊥. La règle de platine est percée, à ses deux extrémités, de deux fenêtres rectangulaires allongées, dans lesquelles émergent deux réglettes de platine portées par la règle de laiton. Ces réglettes sont munies d'une division en dixièmes de millimètre, placée en regard d'une division semblable tracée sur la règle de platine. La règle de platine est, en outre, divisée en centimètres dans toute sa longueur.

Étude.

L'étude de l'étalon bimétallique a consisté en des étalonnages répétés de la règle de platine, comparée mètre par mètre, au prototype N° 26 en platine iridié du Bureau international. Les comparaisons ont été faites dans l'air, les deux étalons étant placés côte à côte dans l'auge à double enveloppe du comparateur géodésique du Bureau, accompagnées, dans chaque intervalle de un mètre, de trois thermomètres étalons. Les déterminations de l'étalon géodésique ont été faites à diverses époques comprises entre le mois d'Octobre 1901 et le mois de Novembre 1902 de manière à permettre, par la variation de la température ambiante, d'obtenir la valeur du coefficient de dilatation de la règle de platine.

La longueur totale des règles de platine et de laiton entre les traits $\frac{\text{Gauche}}{0}$ $\frac{\text{Droite}}{100}$ pour la première et $\frac{\text{Gauche}}{10}$ $\frac{\text{Droite}}{10}$ pour la seconde, a été comparée de même à diverses températures, soigneusement mésurées par huit thermomètres placés de part et d'autre de l'étalon, au niveau moyen des règles de platine et de laiton.

Il a été fait en tout 18 étalonnages complets de la règle en platine, soit 72 comparaisons de ses mètres successifs avec le prototype. Les deux règles constituant l'étalon bimétallique ont été comparées 36 fois entre elles.

La règle de platine a été comparée ensuite à une règle semblable appartenant au Service géographique de l'Armée française, étalonnée à la même époque, ainsi qu'à une règle de fer appartenant à l'Académie des sciences de Suède et employée dans la mesure des bases par la Commission Suédo-Russe du Spitzberg.

Résultats.

Le tableau suivant, dans lequel les observations sont rangées par ordre de températures croissantes, donne les différences entre la longueur totale de la règle de platine et 4 fois le prototype, aux températures moyennes indiquées dans la deuxième colonne, et rapportées à l'échelle du thermomètre à mercure en verre dur :

Observateurs	Température	Pt (0—100) — 4 (26)
M.M. Benoît	3°,859	+ 107μ,2
Guillaume	3°,912	+ 106 ,9
Guillaume	4°,442	+ 104 ,2
Benoît	4°,446	+ 103 ,1
Benoît	5°,691	+ 106 ,9
Guillaume	5°,916	+ 107 ,8
Benoît	6°,840	+ 106 ,4
Guillaume	6°,975	+ 107 ,1
Benoît	8°,716	+ 110 ,8
Tarrade	8°,823	+ 110 ,6
Guillaume et Tarrade...	10°,250	+ 109 ,3
Benoît	10°,266	+ 108 ,0
Benoît	12°,858	+ 111 ,1
Guillaume	12°,915	+ 111 ,9
Benoît	14°,291	+ 114 ,4
Guillaume	14°,416	+ 115 ,2
Guillaume	15°,352	+ 112 ,4
Guillaume	15°,822	+ 110 ,7

En combinant ces résultats par la méthode des moindres carrés, pour le calcul d'une formule contenant un seul coefficient relatif à la température, l'intervalle de température dans lequel on a opéré étant trop peu étendu pour permettre de déterminer un terme quadratique on trouve :

$$[E - 4\,(26)]\,t = +\,109\mu,1 + 0\mu,672\,(t - 9{,}21)$$

Le dernier terme de cette équation exprime le quadruple de la différence des dilatabilités vraies de la règle géodésique et du prototype à la température de 9°,21 moyenne de celles des mesures.

L'équation complète du prototype n° 26 étant

$$[2\, b_t = 1^m + 0,\, 8\mu + (8\mu,\, 596\, t + 0\mu,\, 00170 t^2)$$

et sa dilatabilité vraie à 9°,21 ; 8,627, 10 ⁻⁶ par degré, on trouve pour l'équation complète de la règle de platine en admettant pour les deux étalons la même variation de la dilatabilité.

$$[E_t = 4m + 105,8\mu + 4\,[8\mu,\, 774\, t + o\mu,\, 00170 t^2]$$

Les valeurs individuelles des mètres successifs de la règle de platine ramenées à 0° en adoptant la formule de dilatation qui précède sont :

Premier mètre à 0°	$= 1^m + 21,1\mu$
Deuxième »	$= 1^m + 29,2$
Troisième »	$= 1^m + 32,4$
Quatrième »	$= 1^m + 23,1$

Les comparaisons entre les règles de platine et de laiton, groupées par moyennes de 6 à des températures voisines ont donné

Observateurs	Température	4 — Pt.
M.M. Benoît, Guillaume, Maudet	3°,972	+ 439p,54
» » »	5 ,924	+ 365 ,79
» » »	7 ,965	+ 288 ,05
» » »	9 ,821	+ 218 ,46
Benoît, Maudet, Tarrade	12 ,690	+ 110 ,84
» » »	13 ,976	+ 68 ,31

d'où l'on a tiré d'abord

$$[4 - P]\, t = - 248,42 + 37\mu,\, 287\, (t - 9,06).$$

Le dernier terme de cette équation exprime la différence des dilatabilités vraies au voisinage de la température moyenne des mesures ; 9°,06.

En admettant pour le coefficient du terme proportionnel au carré de la température, la valeur 0,006, 10 ⁻⁶ voisine de celles qui ont été déterminées pour divers échantillons de laiton, on trouve pour l'équation complète de la règle de laiton

$$4 = 4^m - 480\mu,\, 8 + 4\,(18\mu,067\, t + 0,\mu 006 t^2).$$

La compensation de toutes les comparaisons effectuées entre la règle de platine et les deux règles précédemment indiquées conduirait à admettre, pour la règle de platine, à la température de 7°,5 moyenne de ces comparaisons, la valeur

$$E\ 7,5 = 4^m + 369,2\mu$$

d'où l'on déduit

$$E_o = 4^m + 105,6\mu$$

Cette vérification de la valeur $4m - 105\mu,8$ trouvée directement peut être considérée comme extrêmement satisfaisante.

Le Directeur de Bureau,
(Signé) RÉNÉ BENOÎT.

ÉTALLON BIMÉTALLIQUE

Appartenant au Service des Arpentages d'Égypte.

Valeur de la Règle de Platine en fonction de la différence (Laiton Platine).

Les nombres rouges indiquent les températures centigrades correspondant aux longueurs portées dans la table.

RÈGLE DE PLATINE = $4^m + (\ldots\ldots)\mu$

Δ	0	10	20	30	40	50	60	70	80	90
+ 500 μ	+ 2°,33 + 187μ,6	+ 2°,06 + 178μ,1	+ 1°,79 168μ,7	+ 1°,52 159μ,3	+ 1°,25 149μ,8	+ 0°,98 140μ,3	+ 0°,71 130μ,9	+ 0°,44 121μ,4	+ 0°,18 112μ,0	+ 0°,09 + 102μ,8
+ 400 μ	+ 5°,01 281,8	+ 4°,74 272,4	+ 4°,47 263,0	+ 4°,20 253,6	+ 3°,94 244,2	+ 3°,67 234,8	+ 3°,40 225,4	+ 3°,13 216,0	+ 2°,87 206,5	+ 2°,60 197,0
+ 300 μ	+ 7°,68 375,9	+ 7°,41 363,5	+ 7°,15 351,1	+ 6°,88 344,7	+ 6°,62 338,3	+ 6°,34 328,8	+ 6°,08 319,4	+ 5°,81 310,0	+ 5°,54 300,6	+ 5°,27 291,2
+ 200 μ	+ 10°,35 469,8	+ 10°,08 460,4	+ 9°,82 451,1	+ 9°,55 441,7	+ 9°,28 432,3	+ 9°,01 422,9	+ 8°,75 413,5	+ 8°,48 404,1	+ 8°,22 394,7	+ 7°,95 385,3
+ 100 μ	+ 13°,01 563,7	+ 12°,74 554,3	+ 12°,48 544,9	+ 12°,22 535,5	+ 11°,95 526,2	+ 11°,68 516,8	+ 11°,41 507,4	+ 11°,14 498,0	+ 10°,88 488,7	+ 10°,61 479,3
+ 0	+ 15°,67 657,5	+ 15°,40 648,1	+ 15°,15 638,8	+ 14°,88 629,4	+ 14°,61 620,0	+ 14°,34 610,6	+ 14°,34 601,2	+ 14°,81 591,8	+ 13°,54 582,5	+ 13°,27 573,1
+ 0	+ 15°,67 657,5	+ 15°,93 666,8	+ 16°,20 676,1	+ 16°,46 685,5	+ 16°,73 694,9	+ 17°,00 704,2	+ 17°,26 713,6	+ 17°,52 722,9	+ 17°,79 732,3	+ 18°,05 741,6
+ 100 μ	+ 18°,32 751,0	+ 18°,58 760,3	+ 18°,85 769,7	+ 19°,11 779,0	+ 19°,37 788,4	+ 19°,63 797,7	+ 19°,90 807,1	+ 20°,16 816,4	+ 20°,43 825,8	+ 20°,69 835,1
+ 200 μ	+ 20°,96 844,4	+ 21°,22 853,7	+ 21°,49 863,0	+ 21°,75 872,3	+ 22°,01 881,7	+ 22°,27 891,0	+ 22°,51 900,4	+ 22°,80 909,7	+ 23°,07 919,0	+ 23°,33 928,3
+ 300 μ	+ 23°,59 937,6	+ 23°,85 947,0	+ 24°,12 956,3	+ 24°,38 965,6	+ 24°,64 974,9	+ 24°,90 984,2	+ 25°,17 993,5	+ 25°,43 1002,8	+ 25°,70 1012,2	+ 25°,96 1021,4
+ 400 μ	+ 26°,22 1030,7	+ 26°,48 1040,0	+ 26°,75 1049,4	+ 27°,01 1058,7	+ 27°,27 1068,0	+ 27°,53 1077,3	+ 27°,80 1086,7	+ 28°,06 1096,0	+ 28°,32 1105,3	+ 28°,58 1114,6
500 μ	+ 28°,85 + 1123μ,9	+ 29°,11 + 1133μ,2	+ 29°,37 1142μ,5	+ 29°,63 1151μ,7	+ 29°,89 1161,μ0	+ 30°,15 1170μ,3	+ 30°,42 1179μ,6	+ 30°,68 1188μ,9	+ 30°,94 1198μ,2	+ 31°,20 + 1207μ,5
Δ	0	10	20	30	40	50	60	70	80	90

APPENDIX III.

GLOSSARY OF WORDS AND TERMS USED IN THIS REPORT.*

أبعادية ABADIA: Uncultivated lands omitted from Cadastre in 1813; afterwards given in grants to those who could reclaim them.

بحـــــر BAHR: River, natural branch of the Nile.

دفـــتر المساحة DAFTER EL MESSAHA: Land-register prepared by the surveyor, being an index to the map.

داير الناحيـــة DAIR EL NAHIA: The uncultivated road or space round a village.

دلال (دليـــل)* DALLAL: Village measurer who marks out the lands of the inhabitants.

دراع (ذراع)* DIRAA: Cubit; the "Diraa beladi" is equal to 0·58 metre.

دره (ذره)* DURRA: Millet.

فايظ (فايض—فايده)* FAIZ: An allowance given to "Multazims" in lieu of the special tax which the villagers had paid to them.

فـــدان FEDDAN: Measure of area equal to 1·038 acres, or 0·42 hectare, (see page 41).

فلاح (ج فلاحين) FELLAH: (pl. Fellahin): peasant.

جزيرة GEZIRA: Island-land between high- and low-water marks.

غنداق (سجل الاراضى)* GONTAG (Ghondag): Land-register of the time of Mohammed Ali Pasha.

جرن GURN: Threshing floor.

حبـــة HABBA: The twenty-fourth part of a "qassaba" (see page 41).

حوض HOD: A subdivision of the lands of a village, used as a unit area for the imposition of land-tax.

خراجى KHARAGI: Contribuable lands (see page 60).

خارج الزمام KHARIG EL ZIMAN: Land which was not included in the Cadastre.

خـــولى KHOLI: The man in whose name land is registered which is owned in share by many in Nubia (see page 339).

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* The transliteration is of the colloquial words and terms. The classical expressions are given in parenthesis.

مسقة **Misqa**: A small distributing water channel.

ميزانية Mizzania: Index of properties (see page 351).

مواطى Mowati: The lowest of the riparian lands (gezira) on which melons, etc., are grown.

مديرية Mudiria: The seat of the governor of a province.

مكلفة Mukallifa: Land-tax register.

ملتزم Multazim: A concessionnaire (see page 61).

منافع عمومية Munafa Amumia: State Land which is classified as of Public Utility by Decree.

مرتفع Murtafa: The middle group of the riparian lands (gezira) on which wheat, barley and beans can be grown (see page 326).

عمدة Omda: The responsible head of a village.

قصبة Qassaba: A measure of length equal to 3·55 metres.

قبالة Qibala: A subdivision of the lands of a village; in use in Upper Egypt; equivalent to "hod."

قسم Qism: A subdivision or section.

رزقة (انعامية)* Rizqa: Lands exempt from tax and granted in full ownership to the holders or to religious foundations.

سهم Sahm: The five hundred and seventy-sixth part of a feddan, equal to 7·29 square metres.

صاحب التكليف Sahib el Taklif: The registered owner of land.

ساقية Saqia: A water-wheel.

صراف Sarraf: A village tax-collector.

شادوف Shaduf: A bucket-sweep for raising water.

شراق Sharaqi: Land which is not watered by the flood.

شيخ Sheikh: A man of authority or importance in a village; the most influential sheikh is usually made "omda."

تالف Talif: Waste land.

تقسيط Taxit: A deed (see page 61).

عشورى Ushuri: Lands which formerly paid a tax of one-tenth of their produce.

وضع اليد Wadaa el Yad: The occupier of a piece of land.

وسية Wassia: Lands reserved for the Multazim (see page 61).

* The classical expression.

APPENDIX IV.

MEASURES OF LENGTH AND AREA.

LENGTH:

1 diraa beladi = 0·58 metre } Decree of April 28, 1891.
1 diraa mimari = 0·75 metre }
1 qassaba = 3·55 metres. Decree of May 25, 1861.
1 feddan = 333⅓ square qassabas. Defined in 1813.

also

1 metre = 39·370113 inches (La Convention du mètre, 1902, p. 101)

From these relations the following tables are obtained :—

Egyptian.

24 Habbas = 1 Qassaba = 3·55 metres = 3·88233 yards.

English.

1 inch = 25·4 millimetres (correct to 1 part in 1000 000).
12 inches = 1 foot = 0·30 4800 metre = 0·08586 qassaba.
3 feet = 1 yard = 0·91 4399 metre = 0·25758 „
1760 yards = 1 mile = 1·60 9343 kilometres.

Metric.

1 metre = 1·0936142 yards = 3·280842 feet = 0·28169 qassaba.
1 kilometre = 0·6213717 mile.

Qassabas.	Metres.	Yards.	Metres.	Qassabas.	Yards.
1	3·55	3·8823	1	0·28 169	1·09 361
2	7·10	7·7646	2	0·56 338	2·18 723
3	10·65	11·6469	3	0·84 507	3·28 084
4	14·20	15·5293	4	1·12 676	4·37 446
5	17·75	19·4116	5	1·40 845	5·46 807
6	21·30	23·2940	6	1·69 014	6·56 168
7	24·85	27·1763	7	1·97 183	7·65 529
8	28·40	31·0586	8	2·25 352	8·74 891
9	31·95	34·9410	9	2·53 521	9·84 253

Kilometres.	Miles.	Miles.	Kilometres.
1	0·62 1372	1	1·60 934
2	1·24 2743	2	3·21 868
3	1·86 4115	3	4·82 803
4	2·48 5487	4	6·43 737
5	3·10 6859	5	8·04 671
6	3·72 8230	6	9·65 606
7	4·34 9602	7	11·26 540
8	4·97 0974	8	12·87 474
9	5·59 2346	9	14·48 408

Area:

Arabic.

24 sahms = 1 qirat.
24 qirats = 1 feddan.

333⅓ square qassabas = 1 feddan.

1 square qassaba = 12·6025 square metres = 135·6524 square feet.

1 feddan = 4200·83 square metres = 0·00420083 square kilometre.
= 45217·43 square feet = 1·03805 acre.
= 0·00162214 square mile.

1 qirat = 13·8889 square qassabas = 175·035 square metres.
1 sahm = 0·578704 square qassaba = 7·29311 square metres.

English.

4840 square yards = 1 acre.
640 acres = 1 square mile.

1 square mile = 2·58998 square kilometres = 616·540 feddans.
1 acre = 4046·84 square metres = 0·9633448 feddan.
1 square foot = 0·0929030 square metre = 0·00737179 square qassaba.

Metric.

1 square metre = 10·7639 square feet = 0·07935 square qassaba.
1 square kilometre = 0·386195 square mile = 238·0480 feddans.

Feddans.	Hectares.	Sq. Qassabas.	Acres.
1	0·420083	333·333	1·038
2	0·840167	666·667	2·076
3	1·260250	1000·000	3·114
4	1·680333	1333·333	4·152
5	2·100417	1666·667	5·190
6	2·520500	2000·000	6·228
7	2·940583	2333·333	7·266
8	3·360667	2666·667	8·304
9	3·780750	3000·000	9·342

Table for the Conversion of Feddans into Hectares.

Feddans.	0	10	20	30	40	50	60	70	80	90
0	0·	4·20	8·40	12·60	16·80	21·00	25·20	29·41	33·61	37·81
100	42·01	46·21	50·41	54·61	58·81	63·01	67·21	71·41	75·61	79·82
200	84·02	88·22	92·42	96·62	100·82	105·02	109·22	113·42	117·62	121·82
300	126·02	130·23	134·43	138·63	142·83	147·03	151·23	155·43	159·63	163·83
400	168·03	172·23	176·43	180·64	184·84	189·04	193·24	197·44	201·64	205·84
500	210·04	214·24	218·44	222·64	226·84	231·05	235·25	239·45	243·65	247·85
600	252·05	256·25	260·45	264·65	268·85	273·05	277·25	281·46	285·66	289·86
700	294·06	298·26	302·46	306·66	310·86	315·06	319·26	323·46	327·66	331·87
800	336·07	340·27	344·47	348·67	352·87	357·07	361·27	365·47	369·67	373·87
900	378·07	382·28	386·48	390·68	394·88	399·08	403·28	407·48	411·68	415·88
1,000	420·08	424·28	428·48	132·69	436·89	441·09	445·29	449·49	453·69	457·89

Tables for the Conversion of Hectares into Feddans.

Hectares.	Feddans.
1	2·38048
2	4·76096
3	7·14144
4	9·52192
5	11·90240
6	14·28288
7	16·66336
8	19·04384
9	21·42432

Hectares.	0	10	20	30	40	50	60	70	80	90
0	0	23·80	47·61	71·41	95·22	119·02	142·83	166·63	190·44	214·24
100	238·05	261·85	285·66	309·46	333·27	357·07	380·88	404·68	428·49	452·29
200	476·10	499·90	523·71	547·51	571·32	595·12	618·92	642·73	666·53	690·34
300	714·14	737·95	761·75	785·56	809·36	833·17	856·97	880·78	904·58	928·39
400	952·19	976·00	999·80	1023·61	1047·41	1071·22	1095·02	1118·83	1142·63	1166·44
500	1190·24	1214·04	1237 85	1261·65	1285·46	1309·26	1333·07	1356·87	1380·68	1404·48
600	1428·29	1452 09	1475·90	1499·70	1523·51	1547·31	1571·12	1594·92	1618·73	1642·53
700	1666·34	1690·14	1713·95	1737·75	1761·56	1785·36	1809·16	1832·97	1856·77	1880·58
800	1904·38	1928·19	1951·99	1975·80	1999 60	2023·41	2047·21	2071·02	2094·82	2118·63
900	2142·43	2166·24	2190·04	2213·85	2237·65	2261·46	2285·26	2309·07	2332·87	2356·68
1,000	2380·48	2404·28	2428·09	2451·89	2475·70	2499·50	2523·31	2547·11	2570·92	2594·72

ENGLISH AND FRENCH EQUIVALENTS OF EGYPTIAN MONEY.

Egyptian Money to English and French.

Milliemes.	£	s.	d.	Francs.	Centimes.	Milliemes.	£	s.	d.	Francs.	Centimes.
10 =	0	0	2½	0	26	600 =	0	12	3½	15	56
20 =	0	0	5	0	52	700 =	0	14	4¼	18	15
30 =	0	0	7½	0	78	800 =	0	16	5	20	74
40 =	0	0	10	1	04	900 =	0	18	5½	23	33
50 =	0	1	0¼	1	30	1,000 =	1	00	6¼	25	92
60 =	0	1	2¾	1	55	2 L.E. =	2	1	0¼	51	84
70 =	0	1	5¼	1	81	3 „ =	3	1	6½	77	77
80 =	0	1	7¾	2	07	4 „ =	4	2	0½	103	69
90 =	0	1	10	2	33	5 „ =	5	2	6¾	129	62
100 =	0	2	0½	2	59	6 „ =	6	3	1	155	54
200 =	0	4	1¼	5	18	7 „ =	7	3	7	181	46
300 =	0	6	1¾	7	78	8 „ =	8	4	1¼	207	39
400 =	0	8	2½	10	37	9 „ =	9	4	7¼	233	33
500 =	0	10	3	12	96	10 „ =	10	5	1½	259	25

1,000 milliemes = 1 pound Egyptian.

APPENDIX V.

Number of Villages of Which the Old Land Registers Exist in the Government Archives.*

Years.		Provinces.													
A.D.	A.H.	Aswan.	Qena.	Girga.	Assiut.	Minia.	Beni Suef.	Fayum.	Giza.	Qalioubia.	Sharqia.	Dagahlia.	Menoufia.	Gharbia.	Behoeira.
1812	1227	—	—	—	—	2	—	—	—	—	—	—	—	—	—
1813	1228	—	—	—	—	—	—	—	119	125	221	221	233	353	243
1813	1229	—	—	—	—	—	—	2	1	20	3	2	51	2	10
1814	1230	—	—	—	35	333	—	73	96	126	13	182	1	7	31
1815	1231	35	41	—	100	174	—	63	10	62	9	—	278	190	—
1816	1232	1	5	—	—	224	—	5	—	—	—	—	—	—	—
1817	1233	—	—	—	—	—	—	49	1	—	—	—	—	—	—
1818	1234	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1819	1235	—	—	—	—	—	—	1	—	1	65	39	—	—	—
1820	1236	7	—	—	—	3	—	—	—	—	94	285	—	—	—
1821	1237	5	2	—	37	101	89	37	11	—	—	—	—	—	—
1822	1238	—	—	—	—	—	—	—	2	—	—	—	—	—	—
1823	1239	—	—	—	—	—	—	—	2	—	7	—	—	—	—
1824	1240	38	13	—	—	—	—	—	—	—	—	—	—	—	—
1825	1241	15	3	—	—	—	—	—	—	—	—	—	—	—	—
1826	1242	7	—	—	—	—	—	—	1	—	—	18	—	—	138
1827	1243	1	—	111	115	—	—	—	—	—	—	—	—	—	4
1828	1244	14	1	—	—	—	—	—	—	—	—	—	—	—	—
1829	1245	1	210	58	—	—	—	—	—	—	—	—	—	—	58
1830	1246	—	—	—	—	—	—	—	—	—	1	2	—	—	—
1831	1247	—	—	—	—	—	—	—	—	—	—	—	—	—	1
1832	1248	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1833	1249	—	—	—	—	—	—	—	2	1	—	—	—	—	35
1834	1250	—	—	—	—	—	—	—	3	5	—	—	—	—	1
1835	1251	—	—	—	—	—	—	—	1	—	—	—	—	—	71
1836	1252	—	—	—	—	—	—	—	2	—	—	—	—	—	12
1837	1253	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1838	1254	—	—	—	—	4	162	86	—	—	—	—	—	—	—
1839	1255	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1840	1256	34	58	—	—	—	—	—	—	—	—	—	—	—	—
1841	1257	—	—	—	—	—	—	—	2	—	—	—	—	—	—
1842	1258	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1843	1259	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1844	1260	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1853	1270	—	—	—	—	—	163	85	—	—	—	—	—	—	—
1854	1271	—	—	—	—	91	—	—	4	—	—	—	—	—	—
1855	1272	—	—	—	—	2	—	—	3	—	—	—	9	191	—
1856	1273	1	—	104	—	79	—	—	39	—	—	—	17	—	—
1857	1274	—	—	56	—	63	—	—	45	—	—	—	213	—	—
1458	1275	—	—	46	—	55	—	—	16	—	—	—	34	160	—
1859	1276	—	—	53	—	91	—	—	33	—	—	—	34	—	—
1860	1277	—	—	57	—	16	—	—	25	1	—	—	3	—	—
1861	1278	1	—	24	—	18	—	—	12	—	—	—	1	—	—
1862	1279	1	—	30	—	2	—	—	6	—	—	—	—	1	—
1863	1280	—	—	28	—	9	—	—	4	—	—	—	—	—	—
1864	1281	—	—	52	—	—	—	—	7	—	—	—	—	—	—
1865	1282	—	—	34	—	—	—	—	8	—	—	—	—	—	—
1866	1283	—	—	32	—	—	—	—	4	1	—	—	—	—	—
1867	1284	—	—	41	—	—	—	—	1	3	—	—	—	—	—
1868	1285	—	—	132	—	—	—	—	3	—	—	—	—	—	—
1869	1286	—	—	49	—	—	—	—	1	—	—	—	—	—	—
1870	1287	—	—	47	—	—	—	—	—	—	—	—	—	—	—
1871	1288	—	—	49	—	—	—	—	—	—	—	—	—	—	—
1872	1289	—	—	46	—	—	—	—	—	—	—	—	—	—	—
1873	1290	—	—	56	—	—	—	—	—	—	—	—	—	—	—
1874	1291	—	—	46	—	—	—	—	1	—	—	—	—	—	—
1875	1292	—	—	46	—	—	—	—	—	—	—	—	—	—	—
1876	1293	—	—	58	—	—	—	—	—	—	—	—	—	—	—
1877	1294	—	—	73	—	—	—	—	1	—	—	—	—	—	—
1878	1295	—	—	40	—	—	—	—	—	—	—	—	—	—	—

* From lists prepared by Mr. H. G. Skill.

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VALLEY AND DELTA OF THE NILE

LYONS CAD. SUR. EG

PLAN I.

Survey Dept. Cairo, 1908 (358-85)

Scale 1 : 3,000,000

Kilometres 50 0 50 100 150 200 Kilometres

A PORTION OF THE BAHR EL SOHAGIA

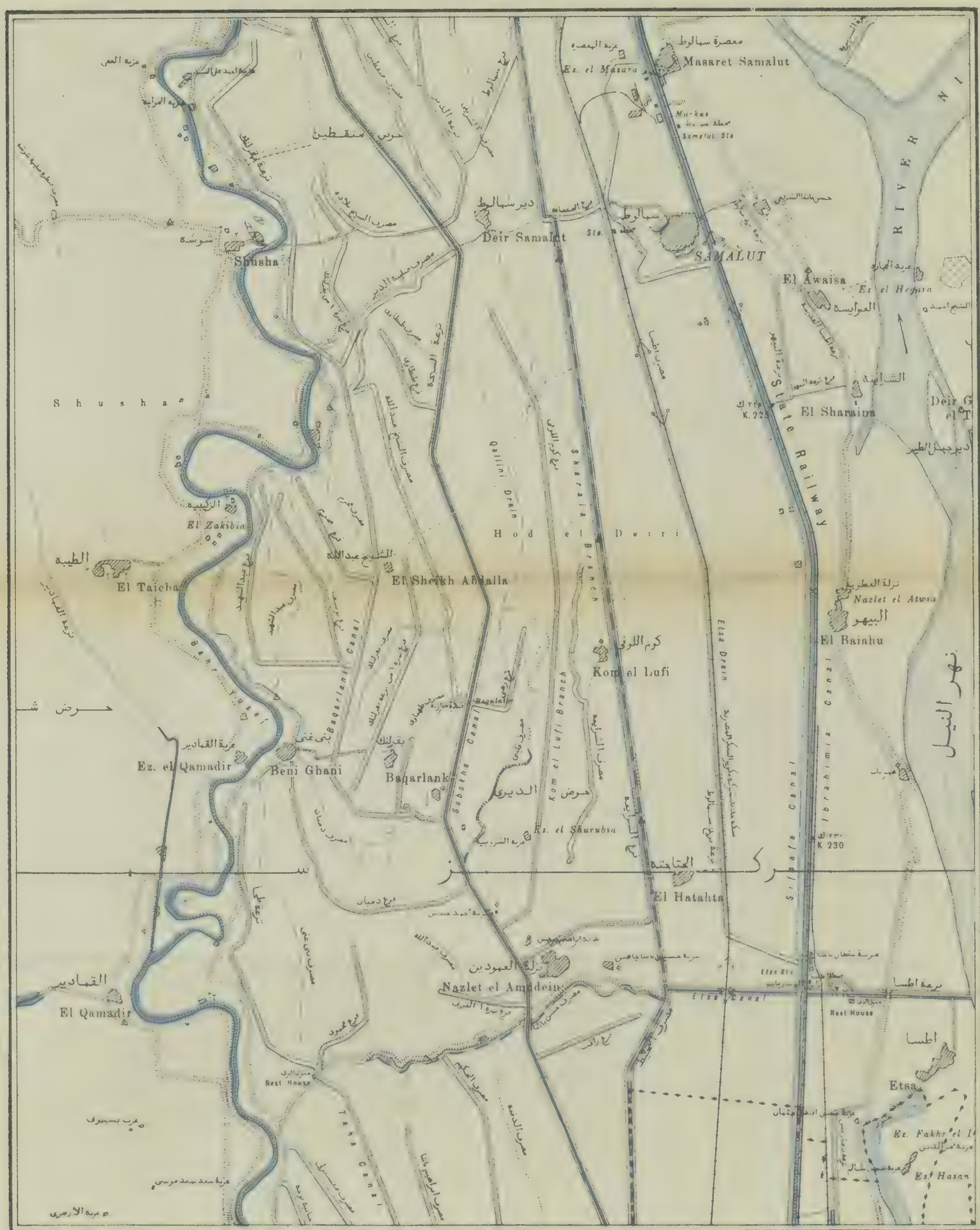
Survey Dept. Cairo, 1908. (355-85)

Scale 1 : 50,000

Metres 1000 500 0 1 2 3 Kilometres

Surveyed in 1904-05

A PORTION OF THE BAHR EL YUSEF



Survey Dept. Cairo 1908 158 85

Scale 1 : 50,000

Metres 1000 500 0 1 2 3 Kilometres

Surveyed in 1905 06

NATURAL AND ARTIFICIAL WATER-CHANNELS IN THE DELTA.

QALIUBIA PROVINCE.

LYONS CAD SUR. EG.

PLAN V.

Survey Dept. Cairo. 1908 (358-85)

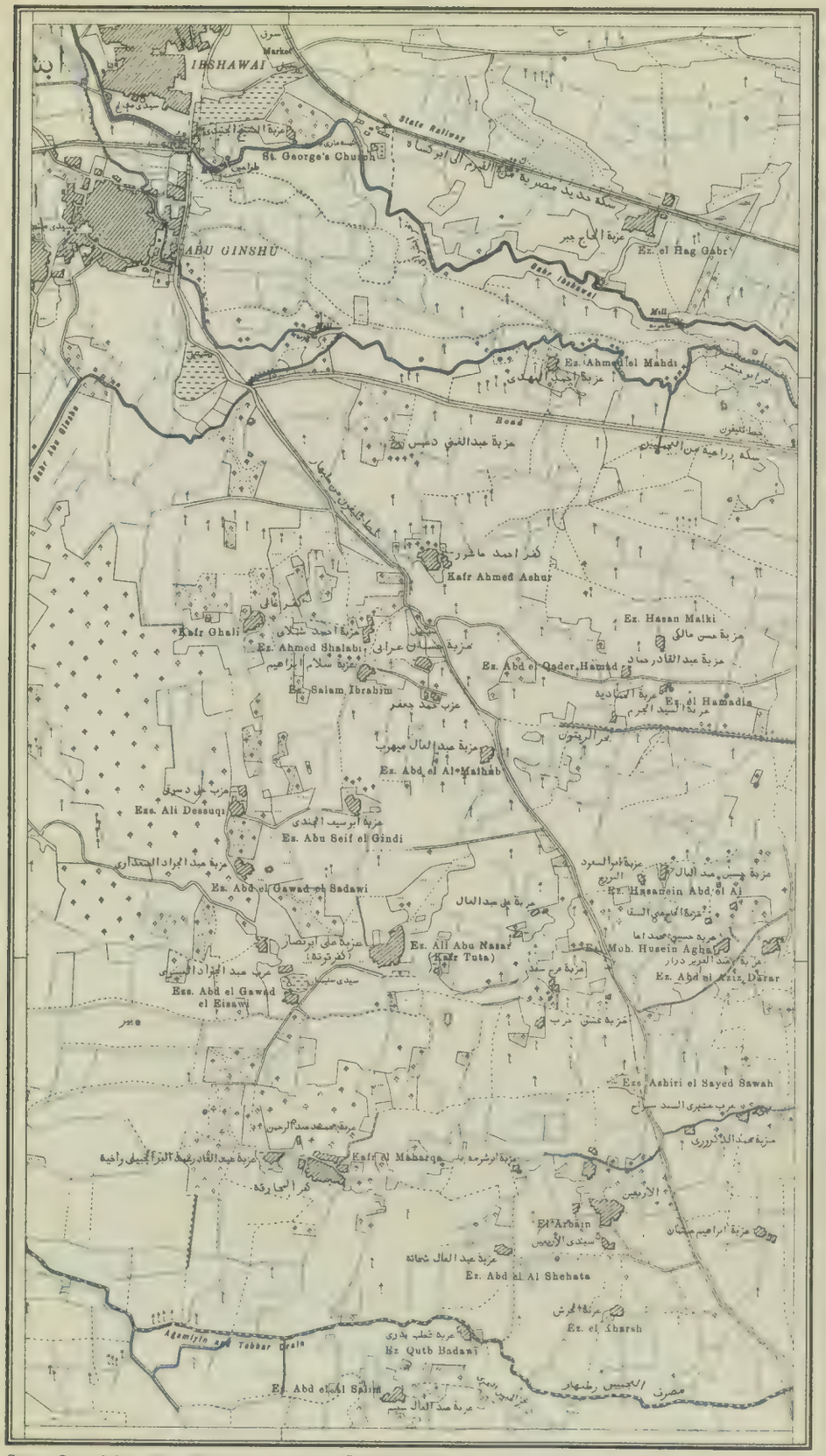
Scale 1 : 20.000

Metres 200 0 200 400 600 800 1000 1200 Metres

LAND IN THE FAYUM AND IN THE NORTHERN DELTA UNDER RECLAMATION.

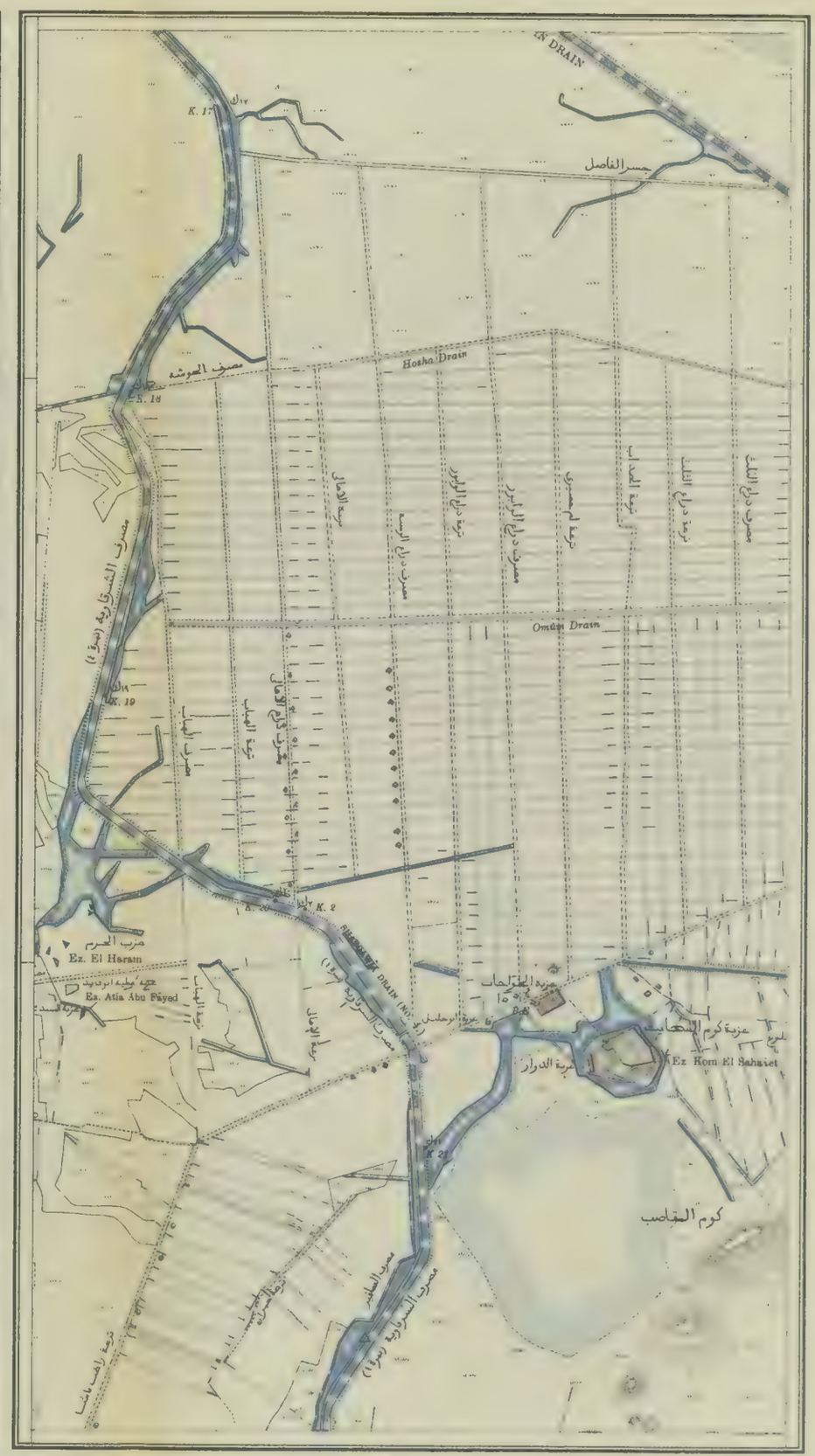
LYONS CAD SUR EG

PLAN VI.



Survey Dept. Cairo, 1908 (358 85)

Fayum Province



Gharbia Province

Scale 1 : 20,000

Metres 200 0 200 400 600 800 1000 1200 Metres

WATER CHANNEL, SILTED UP, BUT INDICATED BY ARRANGEMENT OF PLOTS

LYONS CAD. SUR. EG.

PLAN VII

Scale 1 : 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

Village

IRREGULAR ARRANGEMENT OF PLOTS IN BASIN LAND.

LYONS CAD. SUR. LG.

Sohag district: Girga Province.

PLAN VIII

Survey Dept. Cairo, 1908. (358-55)

Scale 1 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

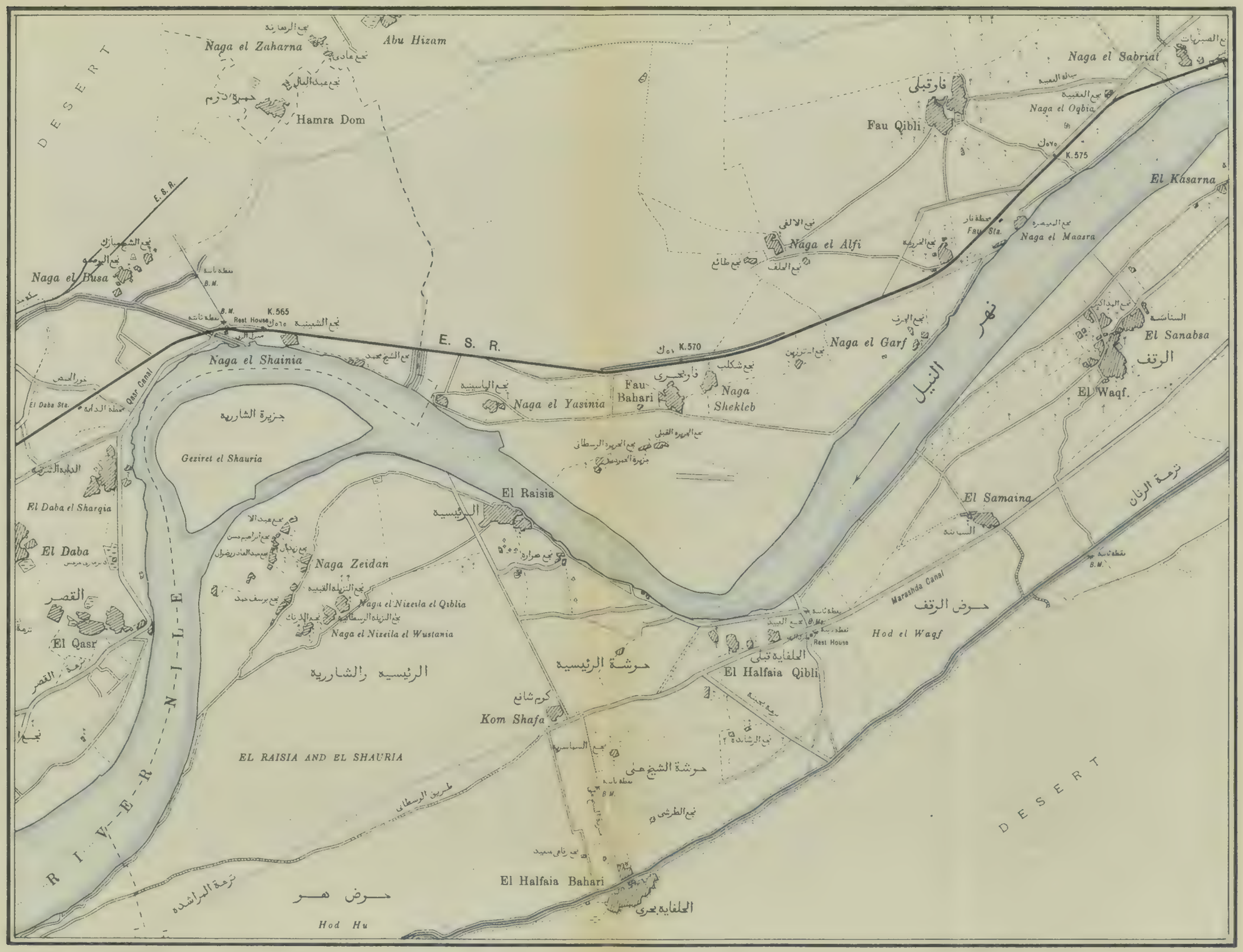
Village

A PORTION OF THE NILE VALLEY NEAR FARSHUT

SHOWING NORTH AND SOUTH USED EQUIVALENT TO UP AND DOWN DOWN STREAM

LYONS, CAD. SUR. EG.

PLAN IX



Survey Dept. Cairo, 1908. (358-85)

Scale 1 : 50,000

Metres 1000 500 0 1 2 3 Kilometres

Surveyed in 1903-05.

A PORTION OF THE VILLAGE HARAGIA, DISTRICT QUS.

SHOWING INTERMIXED HOLDINGS OF COPTIC AND MOSLEM PROPRIETORS.

LYONS CAP. SUR. EG

Shown thus Coptic on white Moslem

PLAN X.

Survey Dept Cairo 1908 (358-85)

Scale 1 : 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

Village

A PORTION OF THE NILE VALLEY NEAR ESNA

SHOWING VILLAGES EXTENDING FROM RIVER TO DESERT

Survey Dept. Cairo, 1906. (358-85)

Scale 1 : 50,000

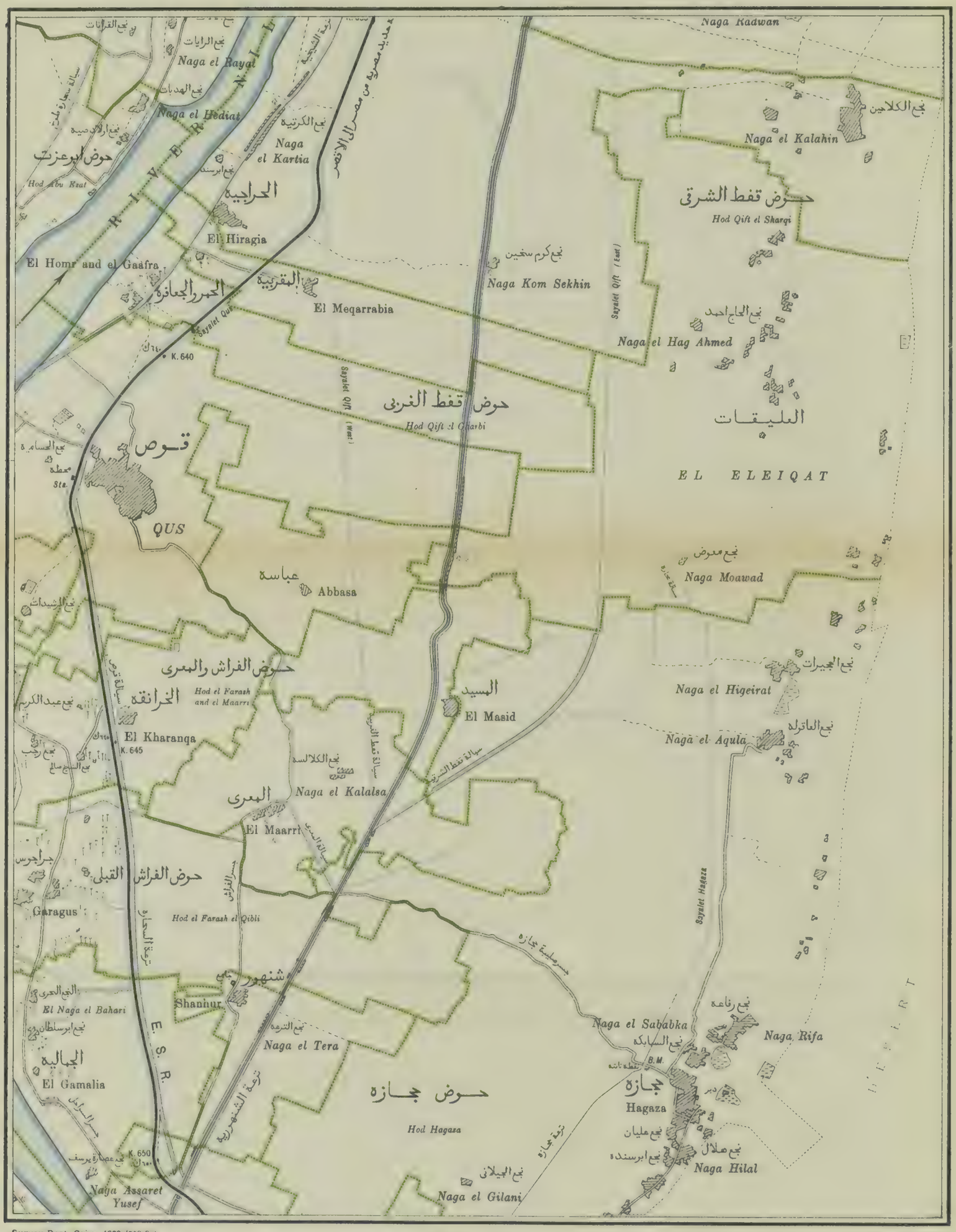
Metres 1000 500 0 1 2 3 Kilometres

A PORTION OF THE NILE VALLEY NEAR QUS

SHOWING SCATTERED VILLAGES NEAR DESERT MARGIN

LYONS, CAD. SUR EG.

PLAN XII.



Survey Dept. Cairo. 1906. (359 85)

Surveyed in 1903-05

Scale 1 : 50,000

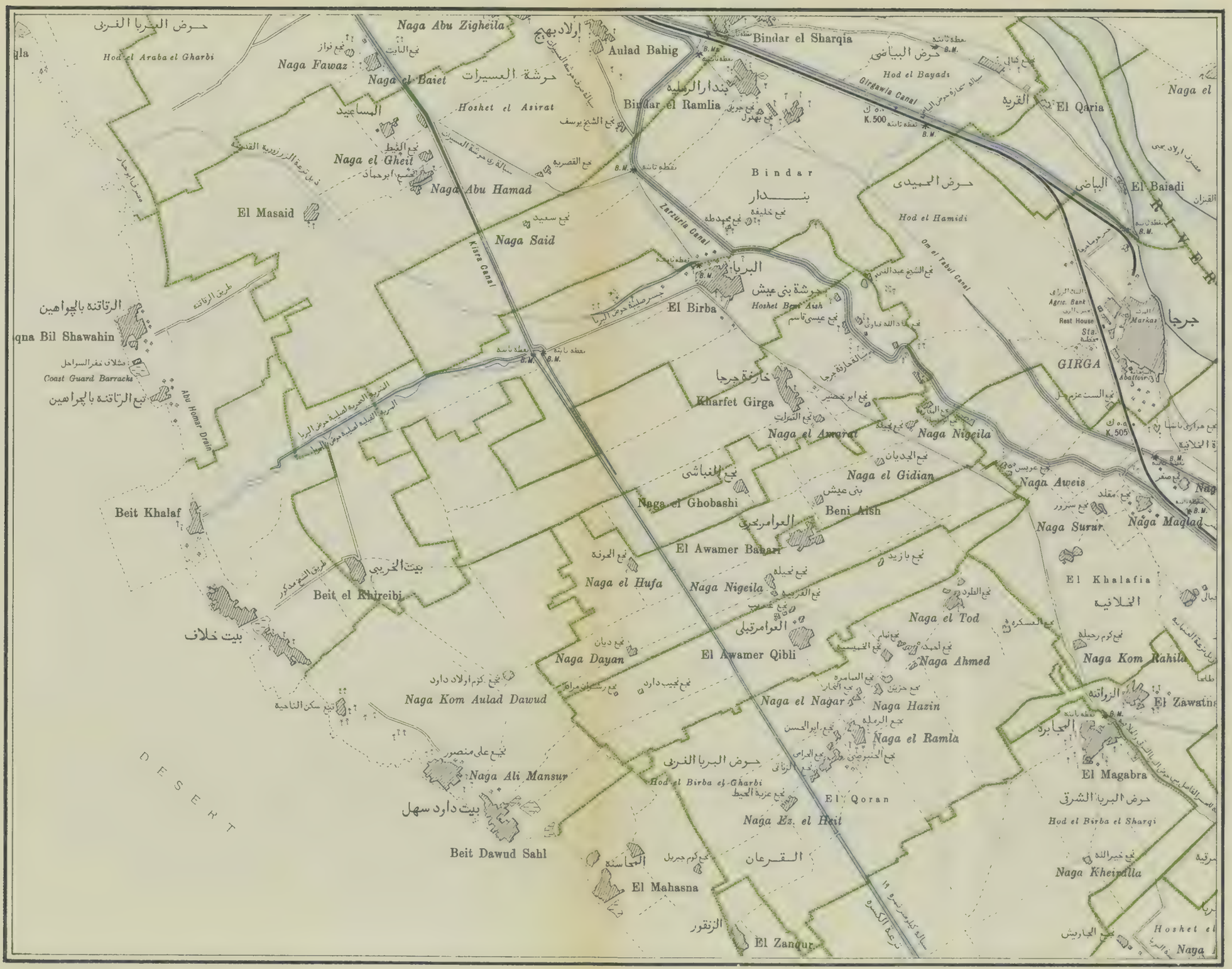
Metres 1000 500 0 1 2 3 Kilometres

A PORTION OF THE NILE VALLEY NEAR GIRGA

SHOWING LONG SHAPED VILLAGES

LYONS. CAD. SUR. EG.

PLAN XIII.



Survey Dept Cairo 1908. (358-85)

Surveyed in 1904-05

Scale 1 : 50,000

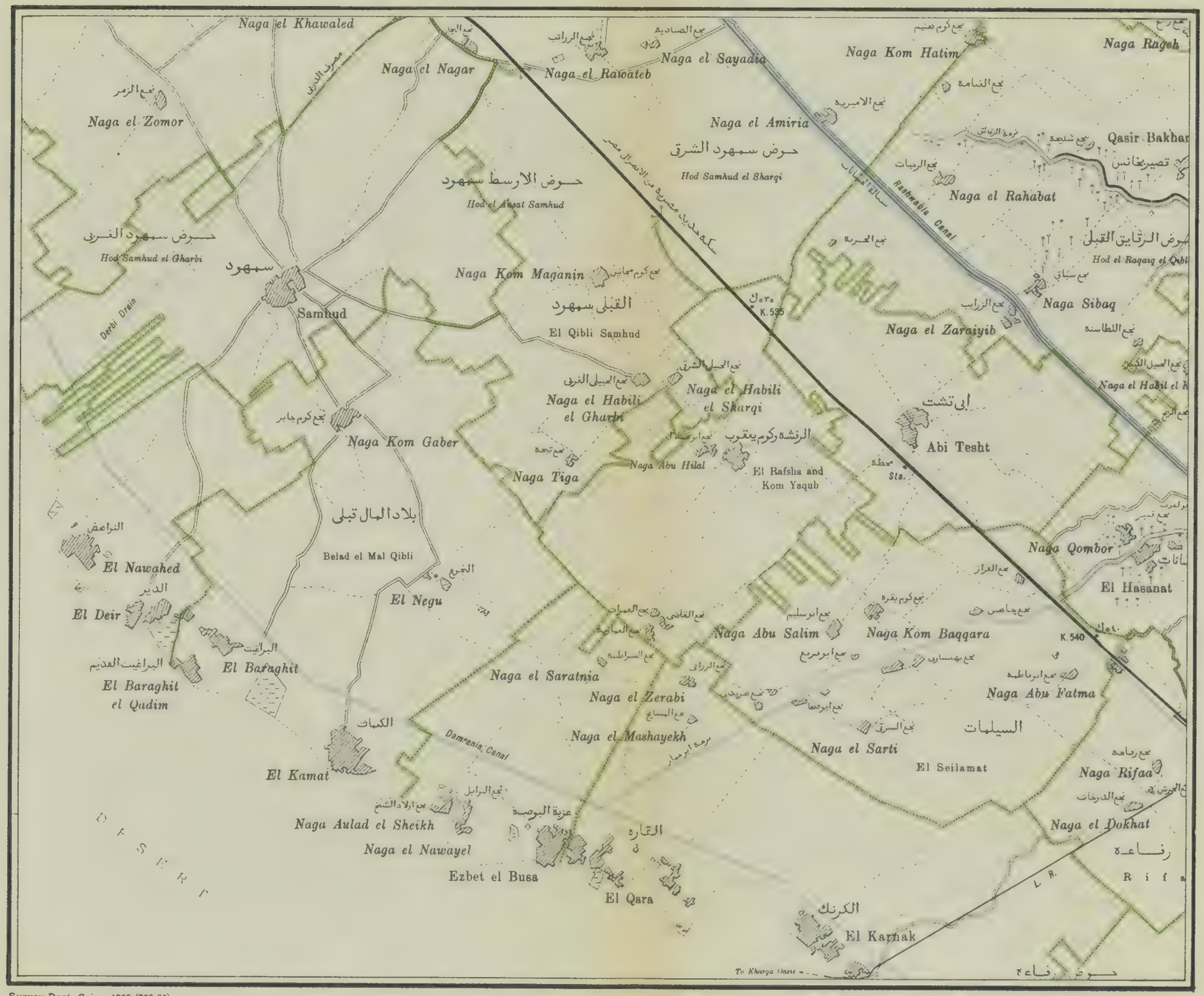
Metres 1000 500 0 1 2 3 Kilometres

A PORTION OF THE NILE VALLEY NEAR FARSHUT

SHOWING INTERLACING BOUNDARIES

LYONS. CAD. SUR. EG.

PLAN XIV.



Survey Dept. Cairo, 1908. (358-85)

Scale 1 : 50,000

Metres 1000 500 0 1 2 3 Kilometres

A PART OF SANDIUN VILLAGE, SHOWING

Houses of village
Gurn or threshing floor
Public utility (canals & banks)
Road round village
Govt. lands

LYONS CAD. SUR. EG.

PLAN XV

Survey Dept. Cairo, 1908. (558-85)

Scale 1 : 5,000

Hod Boundary
Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres
Yards 5 4 3 2 1 0 5 10 15 Yards
Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary
Village

A SHEET OF VILLAGE WANINA EL SHARQIA

SHOWING ARRANGEMENTS OF PLOTS & HODS

PLAN XVI

LYONS CAD SUR EG

Survey Dept Cairo, 1908. (358 85)

Scale 1 : 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

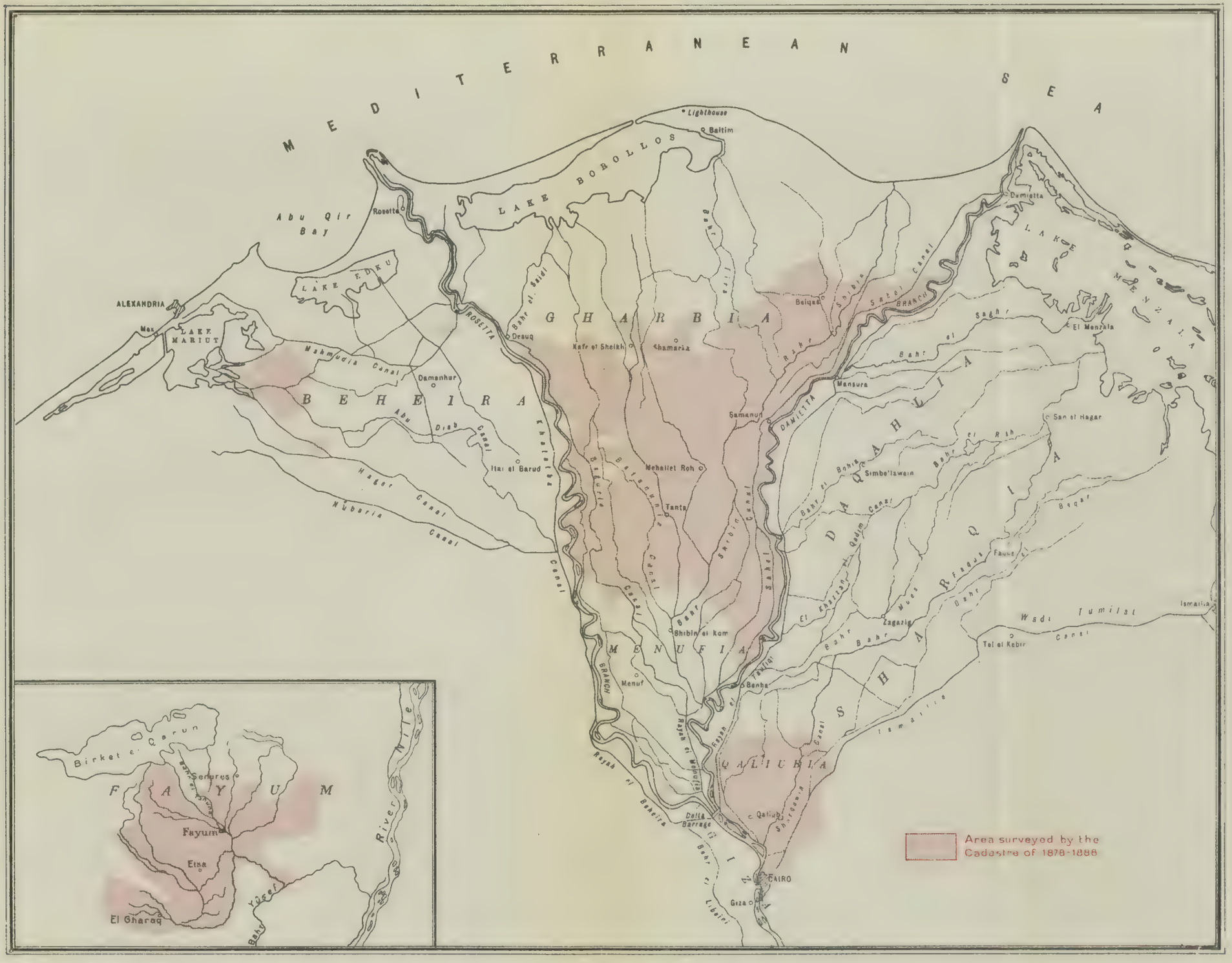
Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

Village

MAP SHOWING AREA SURVEYED BY CADASTRE OF 1878-1888



Survey Dept. Cairo. 1908. (356 85)

Scale 1 : 1,000,000

Kilometres 10 5 0 10 20 30 40 50 Kilometres

A PORTION OF THE VILLAGE KAFR ELLEM

SURVEYED IN 1881.

LYONS CAD SUR EG

PLAN XVIII

Survey Dept Cairo. 1908 (356-85)

Scale 1 : 4.000

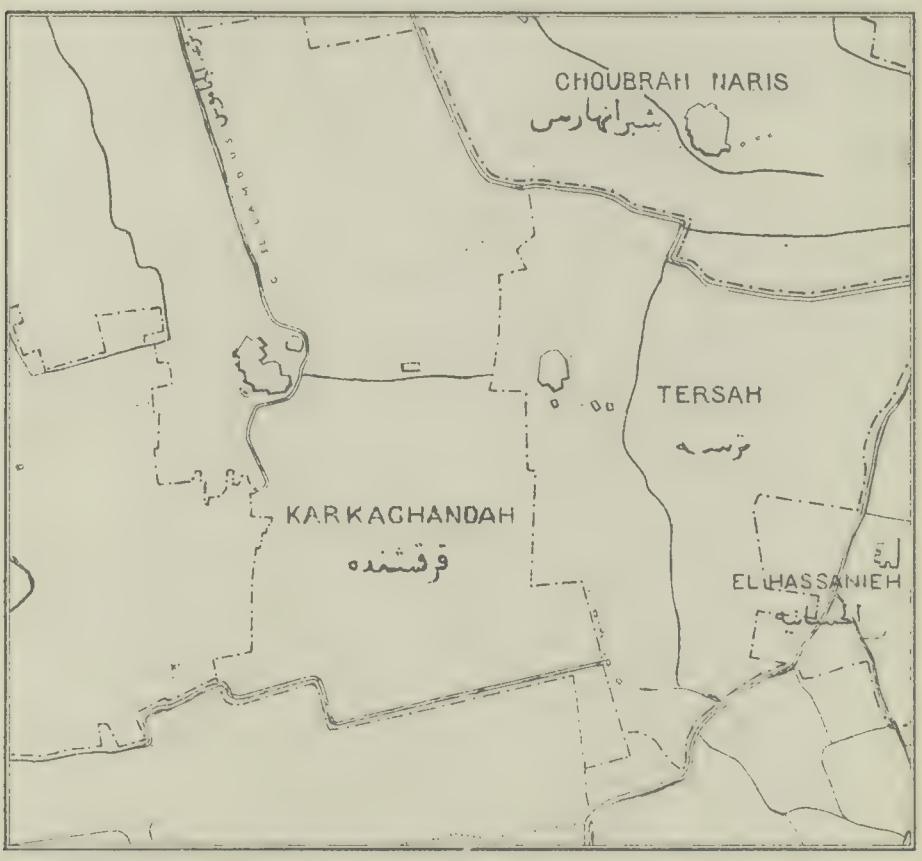
Metres 50 0 50 100 150 200 250 Metres

DISTRICT MAP

COMPILED FROM CADASTRAL MAPS OF 1880.

LYONS CAD. SUR. EG

PLAN XIX.



Survey Dept. Cairo, 1908. (358-85)

ECHELLES

مقاييس

متر Metres

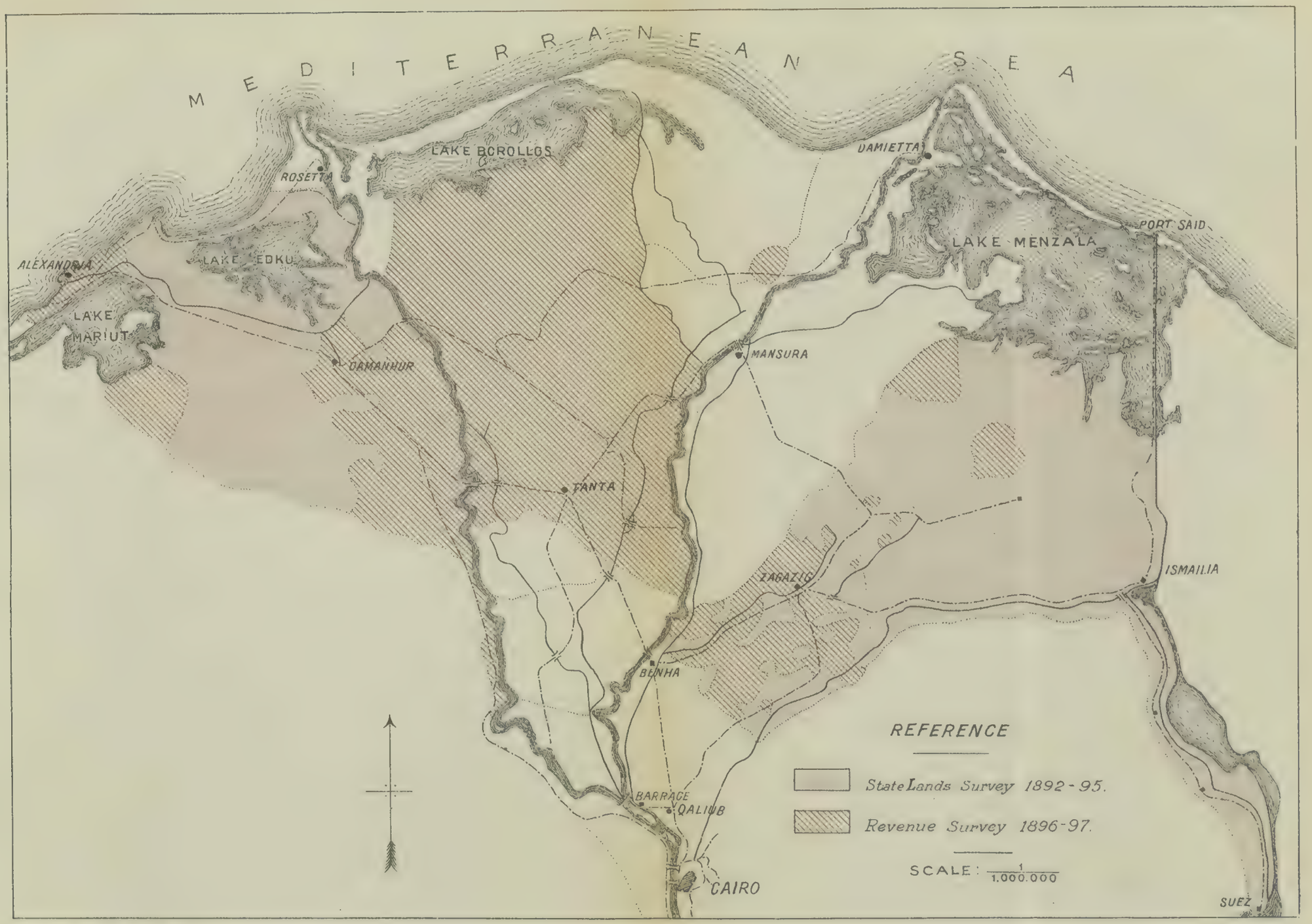
متر Metres

AREA SURVEYED BY THE

STATE LANDS AND REVENUE SURVEYS 1892-1897.

LYONS CAD. SUR. EG.

PLAN XX.



Survey Dept Cairo 1908. (358 55)

A PORTION OF EL MANAGA VILLAGE

LYONS CAD. SUR. EG.

SURVEYED IN 1892.

PLAN XXI.

Survey Dept. Cairo, 1908. (358-85)

Scale 1 : 8,000

Metres 100 50 0 100 200 300 400 500 Metres

A PORTION OF EL MANAGA VILLAGE

LYONS CAD. SUR. EG. SURVEYED IN 1908. PLAN XXI. A

Survey Dept. Cairo, 1908. (358-85)

Scale 1 : 5,000

Metres 5 4 3 2 1 0 5 10 15 Metres

LYONS CAD SUR. EG.

A PORTION OF DAWAMA VILLAGE
SURVEYED IN 1892 BY THE STATE LANDS SURVEY.

PLAN XXII.

Survey Dept. Cairo. 1908 (358 95)

Scale 1 : 8.000

Metres 100 50 0 100 200 300 400 500 Metres

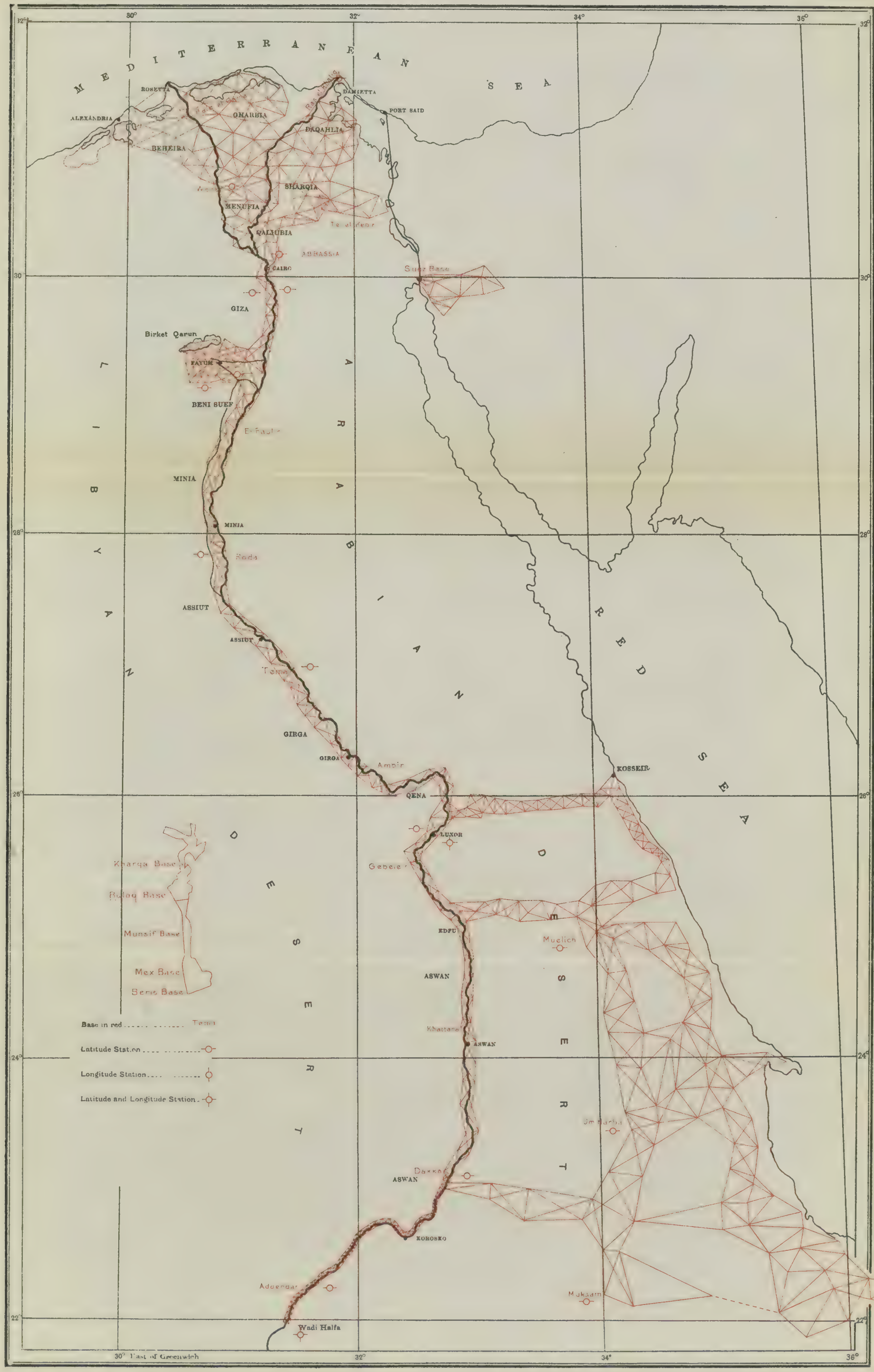
Government lands shown thus

TRIANGULATION 2nd ORDER

COMPLETED UP TO DECEMBER 1908.

LYONS CAD. SUR. EG

PLAN XXIII.



Survey Dept Cairo. 1908. (358 85)

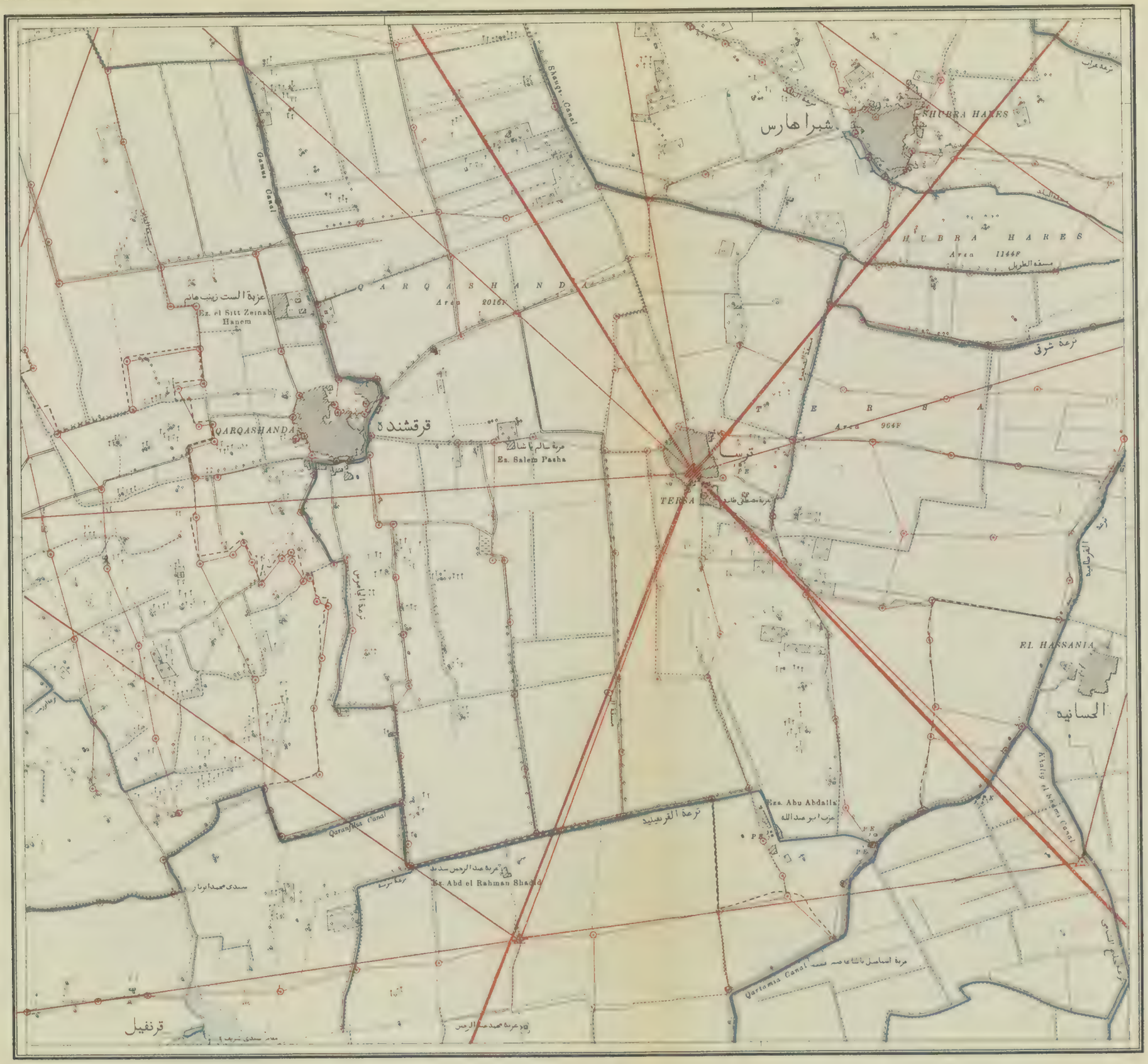
Scale 1 : 3,000,000

LYONS CAD SUR EG

A PORTION OF QALIUB DISTRICT

SHOWING TRIANGULATION AND TRAVERSE POINTS.

PLAN XXIV.



Survey Dept. Cairo, 1908. (356-85)

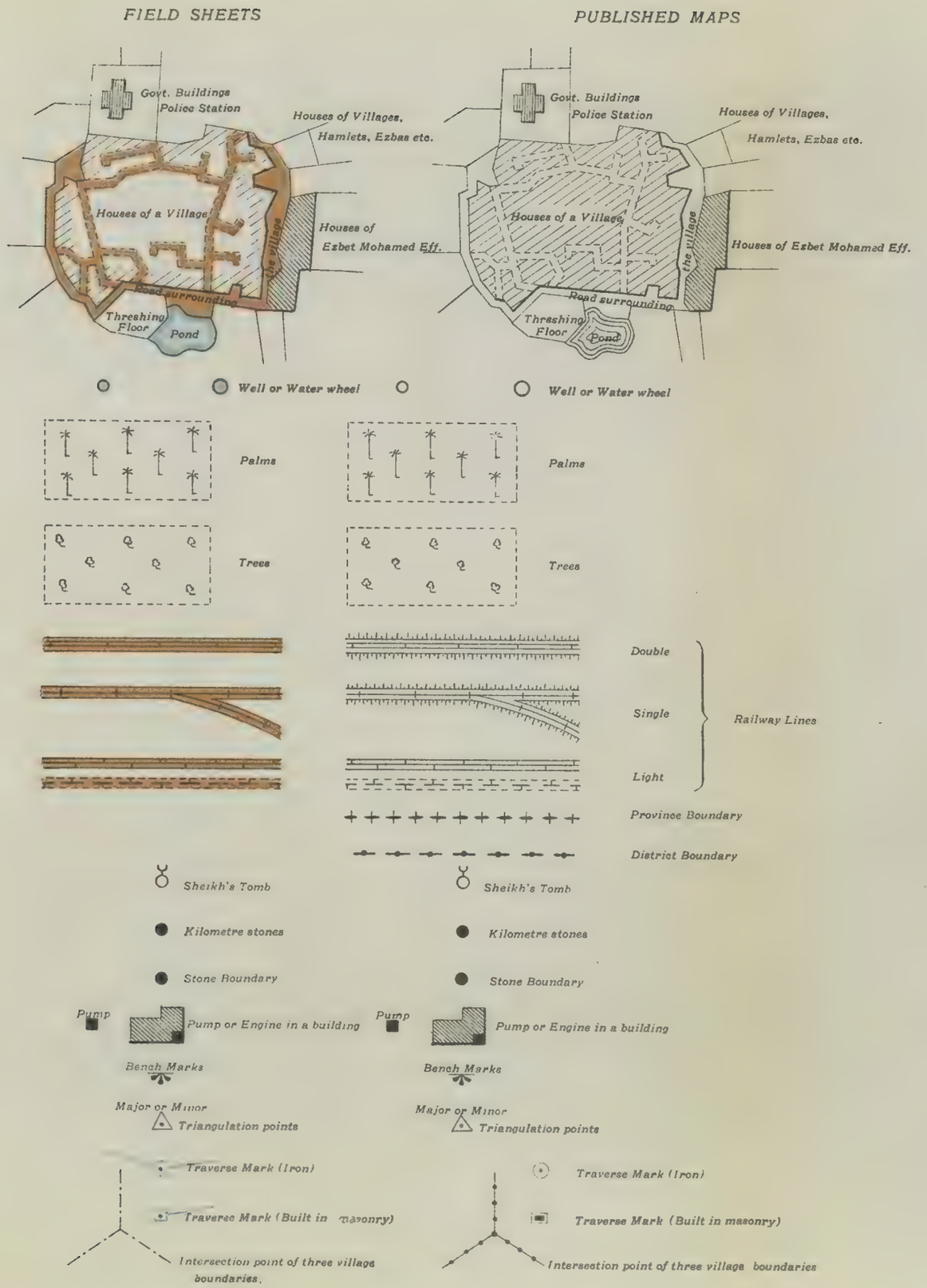
2nd Order point
3rd " "
Traverse "

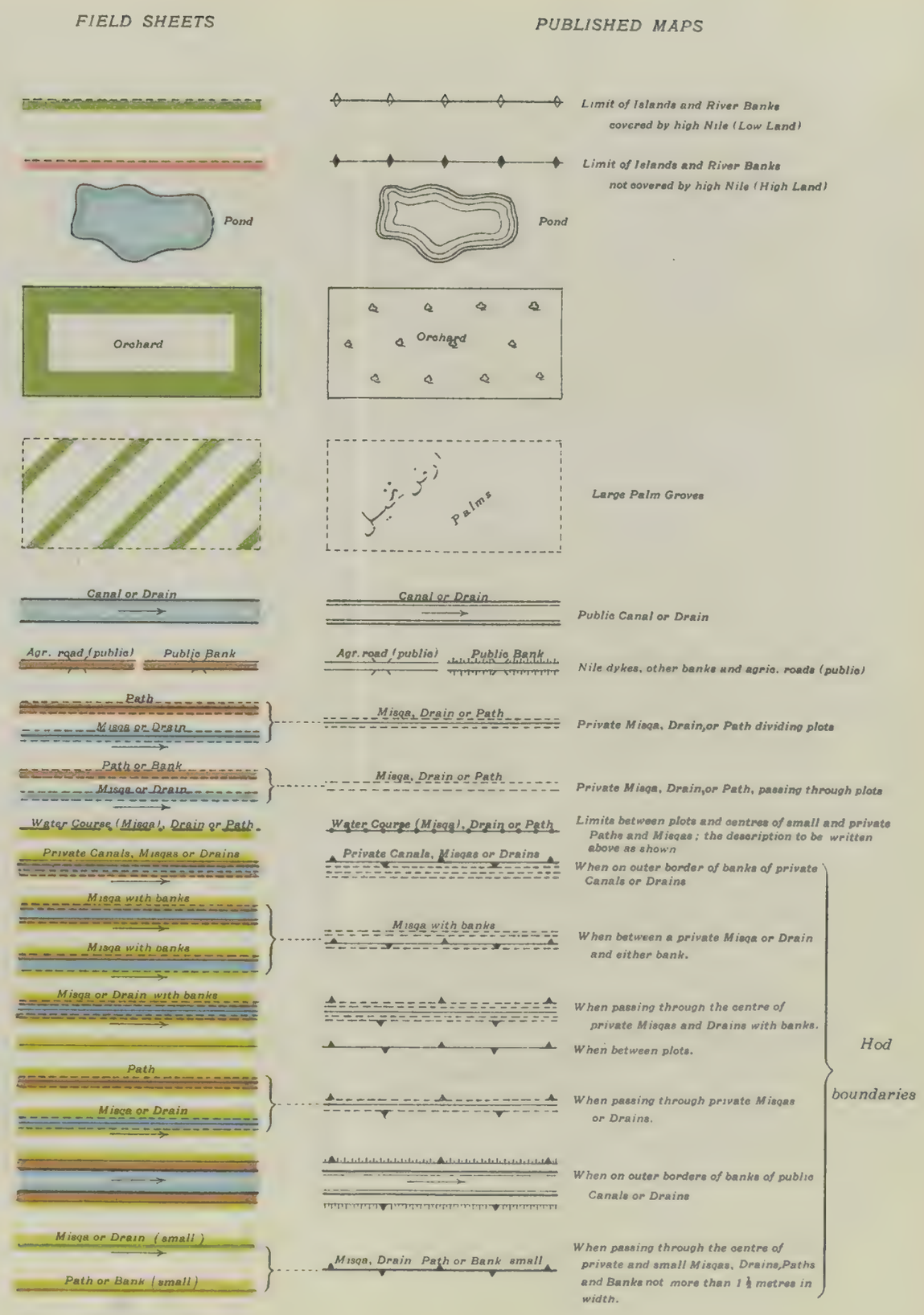
Scale 1 : 20,000

Metres 200 0 200 400 600 800 1000 1200 Metres

2nd Order triangulation line
3rd " " "
Traverse line

CADASTRAL CONVENTIONAL SIGNS.





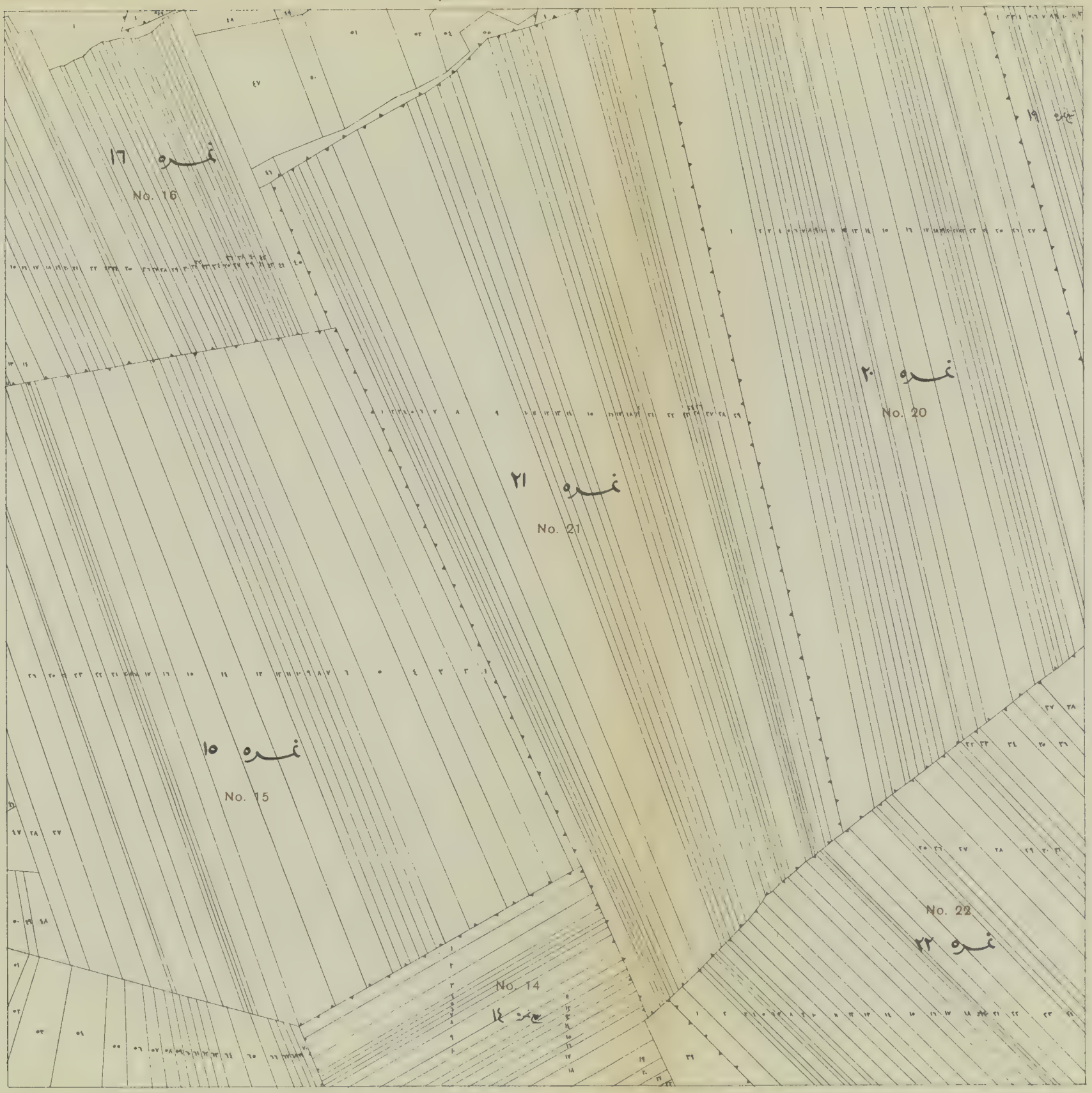
Survey Dept. Cairo 1908 (358-85)

A PORTION OF THE VILLAGE EL LAHUN, FAYUM PROVINCE,

LYONS CAD SUR. FG

SHOWING LONG PLOTS

PLAN XXVI



Survey Dept. Cairo, 1908. (358-85)

Scale 1 : 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

Village

A PORTION OF VILLAGE AGAMEYIN, FAYUM PROVINCE,

SHOWING IRREGULAR PLOTS & PALM GROVES

LYONS CAD. SUR. EG

PLAN XXVII.

Survey Dept. Cairo 1908 (353-85)

Scale 1 : 5,000

Hod Boundary

Traverse Point

Metres 5 4 3 2 1 0 5 10 15 Metres

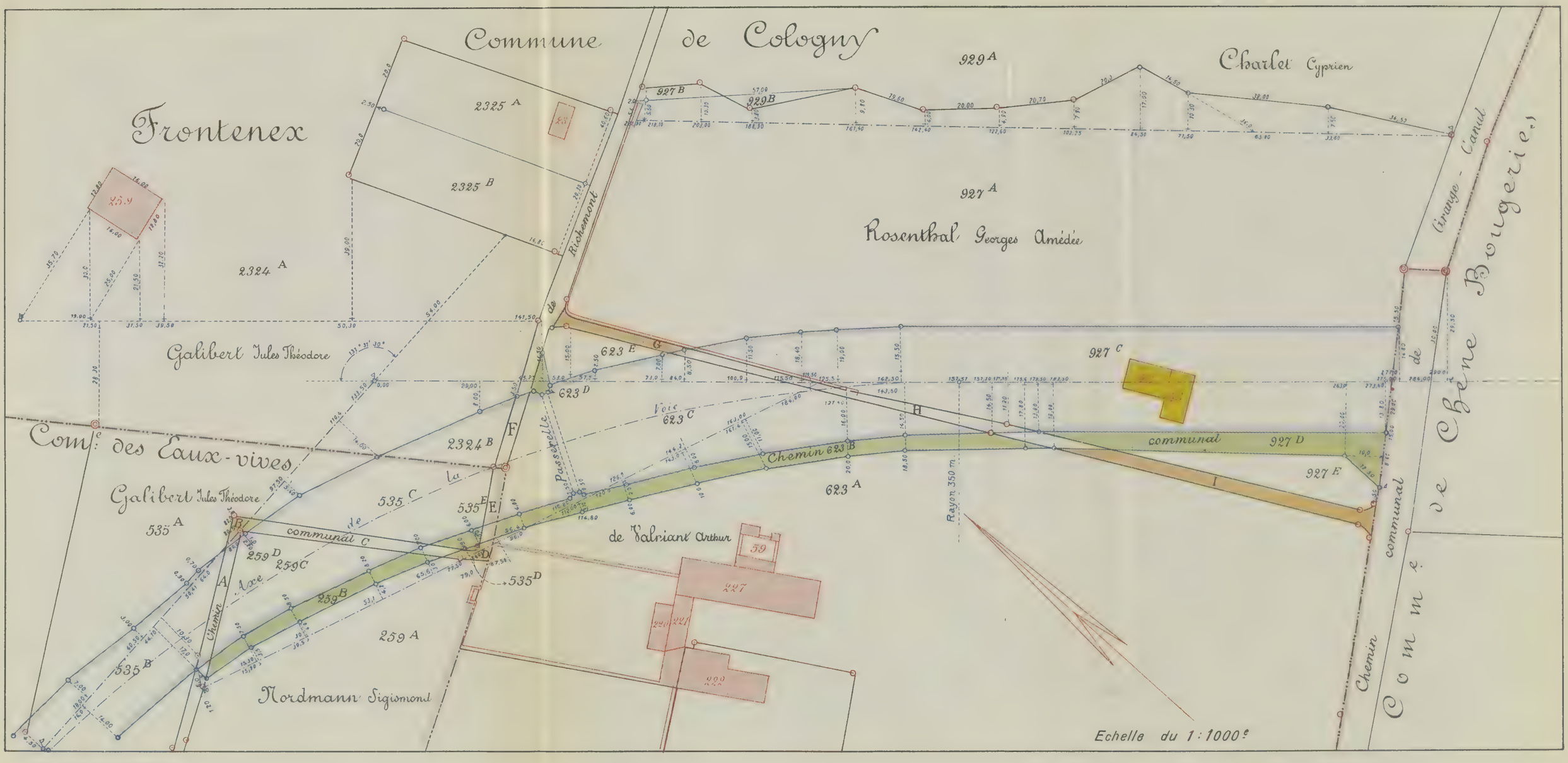
Yards 5 4 3 2 1 0 5 10 15 Yards

Qassabas 5 0 5 10 15 20 25 30 35 40 45 50 Qassabas

District Boundary

Village

METHOD OF CORRECTING A MAP IN THE CADASTRE OF GENEVA.



ناحية نشوه وكفرنشوه وبيشة عامر
مركز مينا القمح
مديرية الشرقية
PLAN XXVIII.
لوحة ١٤-١٠-١٣
١٠-١٠-١٣ تابع حوض التمساح قسم اول نمرة ٢
تابع حوض البحيرة نمرة ١
ترعة بيشة عامر بجسريها عمومية
ناحية نشوه
ناحية كفرنشوه
ناحية بيشة عامر
تابع حوض الخمسيني الفوقاني نمرة ٤
حوض التمساح نمرة ١
تابع حوض القبلة نمرة ٢
تابع حوض الشهدية نمرة ٢
سكن ناحية كفرنشوه عمومي
مسقة خصوصية
طريق خصوصي
مصرف بيشة عامر بجسريه عمومي
مسقة بجسريها خصوصية
سكن خصوصي
شجرة
بركة
جبانة مسلمين
١٣-١٠-١٥
١٣-١٠-١٣
٢-١٠-١٢
الطول ٤٤٣,٥ ملليمتر
العرض ٤٧٩,٦ ,,
Length 445.5 mm.
Breadth 479.6 mm.
ابعاد تمدد او انكماش اللوحه
الطول ٤٤٣,٤ ملليمتر
العرض ٤٨٠,٠ ,,
Sheet dimensions for shrinkage
Length 443.4 mm.
Breadth 480.0 mm.
Survey Dept. Cairo, 1908 (358.85)
Surveyed by me between 23rd June 1906 and 30th Sept. 1906
(signed.) IBRAHIM HEIKAL
Checked and completed under my supervision,
(signed.) AHMED MUSTAFA Engineer,
Passed. 24-4-1907
(signed.) AHMED TAUFIQ Inspector 2nd Taftish. Survey Dept.
مصلحة عموم المساحه بمصر ١٩٠٨
مسحت بمعرفتي من تاريخ ٢٣ يونيه سنة ١٩٠٦ لغاية ٣٠ سبتمبر سنة ١٩٠٦ الامضا ابراهيم هيكل
تراجعت وتمت تحت ملاحظتي الامضا احمد مصطفى مهندس
٢٤-٤-١٩٠٧
نظرت الامضا احمد توفيق مفتش تفتيش ثاني المساحه

Village Kafr Nishwa
Bisha Amer
Nishwa
ناحية كفر نشوه
" بيشة عامر
" نشوه
مركز مينا القمح
MINA EL QAMH DISTRICT.
SHARQIA PROVINCE.
مديرية الشرقيه
شمال شرقى ١٤ - ١٠ - ١٣
PLAN XXIX
حوض التمساح قسم اول نمره ٢
حوض الخمسينى الفوقانى نمره ٤
حوض التمساح نمره ١
حوض القبله نمره ٢
حوض الشهديه نمره ٢
Houses of Village Kafr Nishwa
Bisha Amer Drain (and banks)
Survey Dept. Cairo, 1908. (358-65)
Surveyed in 1907.
Survey Department, Ministry of Finance
Scale in metres 1 : 2.500
مقياس ١/٢٥٠٠ بالمتر
Area representing 1 feddan
Scale in Qassabas 1 : 2.500
مقياس ١/٢٥٠٠ بالقصبه
مصلحة عموم المساحه نظارة المالية

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Menufia Mudiria, scale $\frac{1}{4000}$ and $\frac{1}{2500}$ .. .. / Gharbia " " $\frac{1}{4000}$ .. .. / Qaliubia " " $\frac{1}{2500}$ .. .. / Daqahlia " " $\frac{1}{2500}$ .. .. / Sharqia " " $\frac{1}{2500}$ .. .. / Giza " " $\frac{1}{4000}$ .. .. / Fayum " " $\frac{1}{2500}$ .. .. / Qena Mudiria, scale $\frac{1}{2500}$ .. .. / Aswan " " $\frac{1}{2500}$ .. .. / Girga " " $\frac{1}{2500}$ .. .. / Assiut " " $\frac{1}{2500}$ .. .. / Minia " " $\frac{1}{2500}$ .. .. / Beni Suef " " $\frac{1}{2500}$	50	65
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